DEPARTMENT OF THE INTERIOR, CANADA

Hon. W. J. Roche, Minister; W. W. Cory, Deputy Minister

FORESTRY BRANCH—BULLETIN 38.

R. H. Campbell, Director of Forestry.

FOREST CONDITIONS

IN THE

ROCKY MOUNTAINS FOREST RESERVE

T. W. DWIGHT, M.F.

OTTAWA

GOVERNMENT PRINTING BUREAU

1913

Plate 1 — An Area Lumbered according to Modern Silvicultural Methods.

Courtesy U. S. F. S.

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DEPARTMENT OF THE INTERIOR,
FORESTRY BRANCH,
OTTAWA, April 29, 1912.

SIR,—I submit herewith a report which has been prepared by Mr. T. W. Dwight of his investigations of last season in regard to the relation of the species of timber in the Rocky Mountains Forest Reserve, the effect of the methods of lumbering followed on their reproduction, and the extent to which natural reproduction has followed.

The work that has been done by Mr. Dwight in this way will be of great assistance in determining the methods which are to be followed in the cutting of timber so as to ensure the natural reproduction of the best species. Investigations of this kind enable us to plan methods with greater certainty that the results will be those that we intended to reach. It is important that we should have a thorough understanding of natural reproduction and of the factors which govern it, as we must depend on it very largely for the reproduction of our forests, as reproduction by artificial means will be too expensive to be used extensively at the present time, and we should resort to it only where natural reproduction is clearly not sufficient to accomplish the work.

I would recommend that this report of Mr. Dwight's be printed as a bulletin of this Branch.

Respectfully submitted,

R. H. CAMPBELL,

Director of Forestry.

W. W. CORY, Esq., C.M.G.,
Deputy Minister of the Interior.

DEPARTMENT OF THE INTERIOR,
FORESTRY BRANCH,
OTTAWA, April 16, 1912.

SIR,—I beg to submit herewith a report on 'Forest Conditions in the Rocky Mountain Forest Reserve.' The information contained in the report was gathered by investigations made during the summer of 1911 on the Crowsnest and Bow River forests. The results incident to logging as carried on according to prevailing methods are discussed, and general recommendations as to the silvicultural treatment of the various types of forest are given. Observations made during a month's visit to United States national forests in Montana are embodied in a discussion of methods in use there, both general silvicultural methods and methods of practical regulation of operations.

The report has been written with a view to setting forth specific information that would be of use to technical foresters and others who will be engaged in the planning and carrying out of the management of timber cutting operations, particularly on the Rocky Mountains Forest Reserve, but also on other forests.

Your obedient servant,

T. W. DWIGHT,

Forest Assistant

R. H. CAMPBELL, Esq.,
Director of Forestry,
Ottawa, Ont.

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IN THE

ROCKY MOUNTAINS FOREST RESERVE

GENERAL SILVICULTURAL CONDITIONS.

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SITES AND TYPES.

Mature stands in the Rocky Mountains forest reserve occur in irregular and usually isolated areas, where, for one reason or another, they have escaped the fires that swept over the remainder of the region. This is well shown on the map of the forest contiguous to the boundary, which accompanies the report of the survey of the boundary (Bulletin 18 Forestry Branch). In the unmapped area to the west, larger areas of mature timber occur than those shown on the map, but the general condition is much the same. Not more than twenty-five per cent of the area of the reserve is covered with mature timber, the rest of the forest being second-growth, mostly under fifty years of age and too small to be sawn into lumber, and only occasionally large enough for mine timber or cordwood. The mature stands contain mostly densely grown trees of merchantable size, and yield 5,000 to 20,000 feet board measure per acre.

Three species comprise the greatest part of the timber, and only these need be considered in planning for future crops. Lodgepole pine forms about sixty per cent of the stands, Engelmann spruce thirty-five per cent and Douglas fir five per cent. About fifty per cent of the forest consists of mixed stands of these three species. Of the approximately pure stands, sixty per cent are pine and forty per cent spruce. There are no sites, however, where one tree is found uniformly to the exclusion of the other, and most stands will have at least scattered individuals of second species. A classification of the forest area into three sites would typically show spruce or, under certain conditions, Douglas fir predominating on Site I, and pine on Site III, with a mixed type or a mixture of small pure stands of spruce and pine on Site II.

Site I includes the smooth slopes on the border of the prairie, which have comparatively deep, well-drained soil; and in the mountains it comprehends the bottoms of the valleys and the lower, gentler slopes.

On soils of this first class are often found small stands of well developed Douglas fir. Formerly, more or less extensive stands of this type were in existence, but as this site, on account of its location adjacent to grass-land, has been most exposed to, and most over-run by fires, the stands have been reduced in extent. The type now consists mainly of restricted patches on which the trees are considerably damaged by fire and where the density has been materially decreased or a park-like stand formed. These Douglas fir stands show the maximum development of individual trees in the region, but on account of their present restricted area, they are not relatively of great commercial importance. On account of the well-drained soil, and in some cases by reason of the occurrence of recent fires, the ground-cover is light except where grass has gained a firm foothold, which is usually the case where

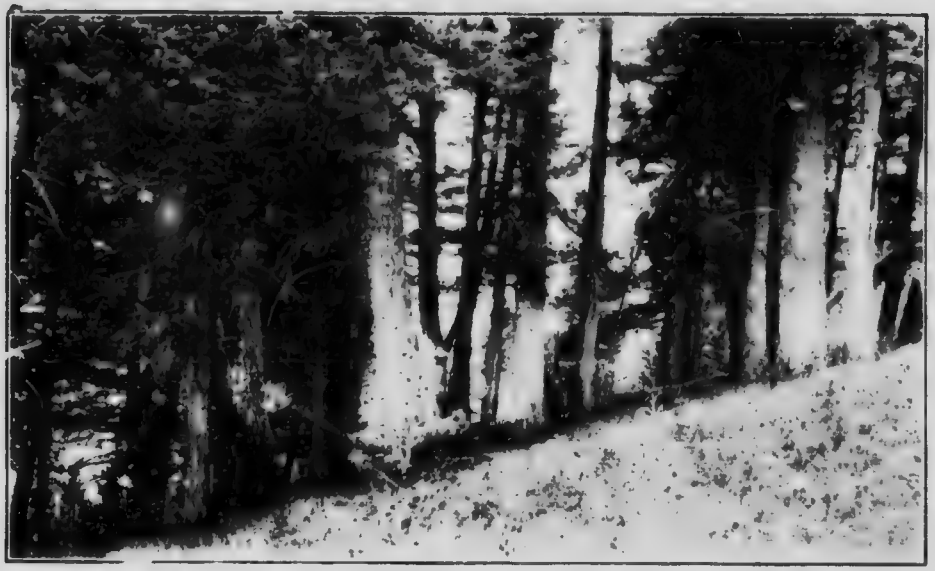

Photo R. H. Campbell.

Plate 2 — Well Developed Douglas Fir.

Photo A. Knechtel.

Plate 3 — Engelmann Spruce Types, with Meadow in Foreground.

the stands have been severely opened up. Since fir seedlings are able to develop even on sod, volunteer growth is usually fairly good, unless it is destroyed by some agent, as cattle or fire.

On Site I farther up in the mountains, and in the moist valleys in the foothills, the pure spruce type predominates. An admixture of scattered pine or Douglas fir, with some small-sized alpine fir (locally known as 'balsam') may form a minor part of the stand. Domination of the type by pine is rather uncommon and mostly confined to the slopes, and can, in many cases, be traced to the influence of some former fire on the composition. Balsam poplar occasionally occurs on the moistest ground, reaching a diameter of thirty inches. It may form narrow strips along the edges of

Plate 4—Pure Lodgepole Pine Type. *Photo A. Knechtel.*

swamps, or be mixed with the spruce. The spruce stands here show considerably lower development of trees and heavier yields than on higher sites. The largest sizes are, as a rule, on the lowest ground, except on broad river-flats where the gravelly raw soil checks the growth and produces stands of small timber. Typical stands have a wide range of size and age compared to stands on other sites. The crown-cover is usually rather dense, and on account of the individual crowns of the shade-enduring spruce trees being also dense, the ground is heavily shaded. The shade, combined with the usually large amount of soil moisture, keeps the surface conditions moist and rather raw, and promotes a rather luxuriant growth of sphagnum and other mosses, which have an important influence on reproduction, as they often form a carpet as thick as four or five inches. Undergrowth is usually light on account of the shade, and consists mainly of a few willows and hazel bushes, but the uneven size of the trees in the stand leaves openings under which occur groups of undergrowth and volunteer growth.

Site II includes the slopes above Site I, extending as high up as the soil remains moderately deep. Here are found stands with spruce and pine mixed in varying

proportions, or pure stands of each species irregularly intermingled. On some aspects, large bodies of pure pine may be found. Where spruce predominates, Douglas fir is found even more frequently than in the spruce stands of Site I, but only to a maximum of five per cent to ten per cent of the stand. Alpine fir (or 'balsam') is of regular occurrence, inferior in size and quality to the other trees of the stand, but occasionally in small groups becoming the dominant species. Stands on Site II are notably even-aged and uniform in character, which makes the boles slender but comparatively free from branches. The largest proportion of clear lumber can be manufactured from trees of these stands. The even-aged character of many of the stands suggests the connection of some definite event with their origin, and in many cases direct evidence may be found that this event was a fire.

The pure pine stands nearly always have scattered spruce trees. These grow slowly in youth, and in even-aged stands are for a long time suppressed by the pine. In young stands, the size of the spruce is smaller than that of the pine, but later the spruce overtakes the pine, and, at maturity of the pine, averages larger in diameter and is growing at a much more rapid rate, as its tolerance has allowed it to keep a comparatively deep crown even in the dense mature stand.

In general, the ground is drier than on Site I, especially where pine, with its short open crown, enters largely into the composition and admits light and air freely. This promotes a better decomposition of the humus and reduces the thickness of the moss layer.

As Site III. may be classified the area on the steeper slopes above Site II, where the dryness and thinness of the soil has checked the growth of the timber, resulting in stands averaging below merchantable size and at best with only the largest of the dominant trees larger than ten inches in diameter. These stands are nearly all even-aged pine stands, but in some cases, especially on northern and eastern exposures, mixed stands of pine, spruce and alpine fir occur. Alpine fir ('balsam') is the commonest associate of the pine, and its reproduction usually forms a large proportion of the volunteer growth. White-bark pine and Lyall's larch are of scattered occurrence near timber line. The number of trees per acre is increasingly high, commensurate with the smaller development.

At the tops of ridges, or in the belt just below the timber-line, there may be found stands of scrub trees whose height-growth is so limited that none of the trees come near reaching merchantable size. In some cases these stands are pure pine, and in others are mixtures of pine, spruce and alpine fir, with the exclusively alpine species. These areas might be separately classified as an extra site, or simply included in Site III.

TABLE 1.

COMPARISON OF SITES (PURE STANDS).

NOTE. The figures are not average ones, and have value mainly for purposes of comparison.

Species.	Trees 8 in. and over. No. per Acre.	Diameter. Av. Max.	Diameter. Average.	Trees 3 to 8 in. in Diam.	Dead Trees	Total.	Volume
		Inches.	Inches.	No. per Ac.	No. per Ac.	No. per Ac.	Ft. B. M.
Spruce.							
Site I	195	23	13·3	100	85	380	26,500
" II	195	17	11·3	225	125	545	18,000
Pine.							
Site I	145	..	12·5	190	95	430	14,680
" II	185	..	9·6	270	110	565	11,920
" III	230	..	9·4	400	130	820	9,160
" V	..	..	..	600	480	1,080	

TABLE 2.

COMPARISON OF TYPES.

(Series of plots taken in a line up a slope where mixture of species continues to timber-line.)

Type.	Site.	No. of Trees and Av. Diam.	Spruce.	Pine.	Alpine Fir (Balsam).
Pure Spruce	II	Number	272	4	4
		Av. Diam.	11·7	9·0	8·0
"	Higher up Slope	Number	192	8	8
		Av. Diam.	11·0	8·5	6·5
Mixed Slope Type	II	Number	124	56	116
		Av. Diam.	8·8	7·6	6·5
"	III	Number	72	96	112
		Av. Diam.	8·4	7·6	7·0
"	Higher up Slope	Number	60	172	112
		Av. Diam.	7·8	9·0	6·9
"	V	Number	100	36	44
		Av. Diam.	10·6	9·2	7·2

TABLE 3.

COMPARISON OF TYPES.

(Series showing change from pure spruce type in valley to pure pine type on the ridge.)

Type.	Site.	No. of Trees and Av. Diam.	Spruce.	Pine.	Alpine Fir (Balsam).
Pure Spruce	II	Number	110	20	10
		Av. Diam.	8·7	5·0	4·0
Spruce and Balsam	II, higher up slope	Number	50	..	40
		Av. Diam.	6·9	..	9·0
Mixed Slope Type	II. "	Number	50	130	80
		Av. Diam.	6·0	7·4	7·0
Pine Type	III	Number		290	
		Av. Diam.		6·1	
Scrub Pine Type	V	Number		380	
		Av. Diam.		4·5	

VOLUNTEER GROWTH.

The practical importance of volunteer growth is not very great, on account of the even-aged character and high density of average stands. In spruce stands, it consists of sparsely located spruce or alpine fir ('balsam') seedlings. The entrance of pine into the composition frequently increases the amount of volunteer growth on account of its giving opportunity through its open crown for increased amounts of light to reach the ground. Pine itself seldom becomes an important constituent of the body of volunteer growth, as its seeds do not readily germinate on the seed beds found ordinarily under mature trees on any site, and the amount of light available in most stands is not sufficient for the development of the seedlings. Occasionally where a ground-fire has run through pine stands, volunteer growth of pine may be present in considerable amounts. In pine stands on upper slopes, alpine fir is a more persistent associate of the pine than is spruce; and, as its seedlings start even more readily than those of spruce on the natural forest floor, an increasing preponderance of alpine fir reproduction is often, though not invariably, to be noticed with an increasing proportion of pine in the mature stand.

Quantitative observations of the actual number of seedlings forming the body of volunteer growth that might form the basis of a new stand after the present one is logged off do not, in general, give results very encouraging. The general conclusion that is forced on one is that provision must be made for a stock of seedlings to start after the old crop is removed, if a satisfactory young stand is to be obtained. Where only a portion of the total stand is to be removed, as in a selection system, the volunteer growth may be counted on often to fill up a large proportion of the openings made. In every case, on account of the shade-enduring qualities and the consequent power of recovery of a normal rate of growth after suppression possessed by the species forming the largest proportions of the volunteer growth, this form of young growth is valuable and should have all possible protection afforded it during logging operations.

INFLUENCE OF ALTITUDE.

The influence of altitude on the tree growth of the east slope of the Rocky Mountains is due more to topography, in its effect on the depth and moisture of the soil, than to variations of atmospheric conditions either of temperature or of rainfall, which usually are extremely important factors in tree distribution in mountainous regions. The latter factors here limit the range of only minor species; the two main species, spruce and pine, may commonly be found occurring at any position between timber line and the bottoms of the lowest valleys. The variation in altitude is not as great as in some regions, and the high elevations are confined mainly to narrow ridges. The main valleys, even within moderate distances of the continental divide, lie between 4,000 feet and 5,500 feet, and timber line is usually about 7,000 feet high. This is a comparatively narrow range of elevation to which the tree growth is confined. The higher elevations, which run up to 11,000 feet in extreme cases, and 9,000 feet on the average, are found only on the high, narrow ridges, which lie usually in parallel directions, and above timber line have very steep and rocky exposures. This bare rocky area is only a small proportion of the total land surface. It is the steepness and lack of soil, coupled with exposure to storms, that limits the tree growth, and if sufficient protection and soil is afforded, practically all of the main species will grow to the highest elevations. What the relative effect of atmospheric and soil conditions is on the rate of growth is hard to say, but it is probable that the thinness of the soil is the chief factor retarding growth at the higher elevations and limiting the size of the tree, although the frequent occurrence of frost would certainly have an important effect.

INFLUENCE OF ASPECT.

The influence of aspect on the forest type can be traced only in certain localities. In many places only minor and irregular differences can be observed between stands on slopes facing in various directions. However, marked contrasts frequently exist between the types on slopes facing in opposite directions, and comparison from place to place shows a fairly consistent effect to be attributed to the differences in aspect. The contrast is usually between these two conditions: on the one hand, a rapid change from the spruce type of the valley to pine on the slope, the pine becoming progressively purer as higher elevations are reached and, near the timber line, scrubby in character; on the other hand, the occurrence of spruce in considerable proportion right to timber line, in mixture with pine, alpine fir ("balsam") and also Douglas fir, with whitebark pine and Lyall's larch near timber line. The two series of stand-tables previously given to show the altitudinal variation in type illustrate contrasts which may be observed on different aspects. The predominance of pine is found usually on south and west exposures, and the mixed type on [illegible] aspects. The south and west exposures are much the driest, not only [illegible] sun's rays more directly and for a longer time each day, but also [illegible] winds from the south and west, which are especially warm and dry [illegible] the Chinook influence incident to the passing of the air currents [illegible] nental divide to [illegible] elevations.

The manner in which this influence of aspect directly affects [illegible] forest is hard to explain. The occurrence of thrifty trees of both [illegible] pine in considerable numbers on both aspects precludes the idea that the [illegible] trees is hindered sufficiently to gradually give one species the advant[illegible] aspects. The influence of the aspect on the character of the stand is [illegible] its influence on factors which govern the character of reproduction. [illegible] the drier sites would be more apt to have intense fires and also light [illegible] both of which favour pine reproduction, while the moister sites would be more [illegible] able to the reproduction of spruce, fir and alpine fir ("balsam"), and more have seed-trees of those species left after a fire.

SECOND-GROWTH STANDS RESULTING FROM FIRES.

These occupy three quarters of the forest area and the timber is [illegible] per cent pine, the remainder being mainly spruce or, in the foothills, pe[illegible] reasons for the dominance of pine over spruce are explained in the dis[illegible] the influence of fires. There does not seem to be any limit to the peri[illegible] which fires have occurred. An extensive fire occurred in the Ghost River [illegible] hundred and eighty-three years ago, and the resulting stand is now being [illegible] Evidences of fire are found in still older stands and the general even-aged [illegible] of the forest indicates the extensive influence of past fires on the present [illegible] of the forest.

Within the past sixty years, fires have increased greatly in number, judging from the ages of most of the second-growth stands, which lie below that age. An extensive fire occurred in the vicinity of the Sheep River forty-five years ago, and widespread fires have been periodical events there during more recent times. The splendid reproduction of pine, even after very severe fires, has been a boon to the forest, since practically all the burned-over areas have seeded up to merchantable species instead of, as in many regions of Canada, coming to be occupied by comparatively worthless species. Under conditions unfavourable to reproduction, occupation of the burned areas by grass takes place; and that is the worst result than can come of a fire, or of repeated fires. Of course, on most natural forest areas, except in moist valleys, the

grass-land is very poor in quality and that condition is not one to be regarded very favourably, because the maintenance of tree growth would keep the productive capacity of the land greater.

INFLUENCE OF DENSITY.

The chief disadvantage of the present condition of second-growth stands is their too great density. This is a serious disadvantage, especially in the pine stands. Pine seeds up very thickly after fires and its tolerance is sufficient to prevent a rapid decimation of the young trees, and so many trees remain alive that none are able to develop rapidly into large-sized material. Thinning would be an effective remedy; and where fence-posts, fuel, &c., are in demand, it might be carried out on a small scale; but with the vast majority of second-growth stands, it will be necessary to wait the extra length of time necessary to the development of useful material.

The normal number of trees in second-growth stands varies, of course, with site and age. On Sites I and II, where the soil conditions are fairly good, differences in rates of growth do not become marked until after fifty years, so that average figures can be given for the two sites up to that age. About 1,000 trees per acre, one inch and over, is normal at fifty years, and at that age the dominant trees are about eight inches in diameter, and forty to fifty feet high. At twenty-five years, the same stand would have had about 1,500 trees. In dense stands, a larger proportion of the trees are in the suppressed class than where the total number per acre is smaller. In a plot with 3,000 trees per acre, there were 1,400 dead suppressed trees. That indicated a very high density in early youth.

The following table of normality is used by reconnaissance parties in lodgepole pine forests in Montana. It aims to give quantitative expression to the effect of over-stocking on the yield, similar to that of under-stocking.

TABLE 4.

TABLE OF NORMALITY.

Density up to 60 years.	Normality.
900-1200	Normal
1200-1500	0·9
1500-2000	0·7
2000-3000	0·5
3000 and over	0·3

In practice a plus sign (*e.g.*, 0·9+) is placed after the figure of normality to indicate over-stocking, rather than under-stocking.

In mature stands, the variation in diameter resulting from different densities is marked. Among fourteen plots, those three having trees of the largest average diameters had the smallest total number of trees. The remaining plots, when arranged according to density, showed successively decreasing diameters. Since the range of average diameters was only from eight inches to twelve inches and the minimum size of merchantable trees lies between eight inches and ten inches, it is apparent that a small variation in the average diameter makes a very great difference in the number of trees merchantable. Also, the merchantable contents of trees and the value of the material obtained increase relatively very rapidly with increase in diameter.

From a consideration of sample plots, it would appear that the maximum density of mature stands consistent with proper development lies between 400 and 600 trees per acre, three inches and over, of which only 200 to 250 trees would be over eight inches. The optimum lies in the neighbourhood of 300 to 400 trees per acre.

AGENTS AFFECTING CONDITION OF FOREST.

LUMBERING.

METHODS OF OPERATION.

Logging operations are confined to the areas of mature timber, of which the accessible ones are nearly all included in timber berths licensed previous to the formation of the forest reserve. Applicants for berths have been mainly attracted by areas of spruce timber on account of the large average size of the trees. The timber on the berths is cut under the general regulations for the cutting of timber on Dominion lands, which fix a diameter limit of ten inches at the stump, and provide for the leaving of seed-trees, for brush disposal, and for the protection of young timber.

The methods of logging are adapted from those in vogue in Northern Ontario and the Lake States, as most of the lumbermen and woods-foremen gained their experience in those regions. The general conditions are also similar with the exception of some characteristics of the topography. The steepness of the slopes in this region increases the difficulty of skidding the logs and constructing the roads. The general plan of logging is, in the fall, to construct roads, and begin the felling of timber, the latter being continued until January, when the arrival of sufficient snow allows hauling to begin. In most cases, the rivers are utilized to transport the logs to the mill, sometimes fifty miles or more.

Camps are built with log walls and roofs of lumber or, sometimes, poles, and are designed to accommodate forty to sixty men, for which five or six buildings are necessary. Merchantable timber is nearly always used, since the trees that reach a size large enough for building logs are practically all of merchantable species. Tote-roads are carefully constructed, and have fairly easy grades in general, as they are confined to the valleys and do not have to climb to high elevations. The chief difficulty in their construction is digging out a level roadbed on hill-sides, and constructing bridges over gullies. Swamp land, which necessitates building corduroy, is limited in amount. A large proportion of the toting of supplies is done on wagons, so that good roads are required.

Felling is done by both two and three-men crews, and skidding by single horses in small pine or by teams in heavy spruce. The logs are rolled on skidways by men with cant-hooks without the aid of a horse and decking chain. Hauling is done on double sleighs with six or eight-foot bunks. Most of the roads are not iced, though that is done on the most important ones. Driving has, in most cases, not involved the construction of dams, the main rivers being driven without assistance of this sort, mainly by reason of their swift current. At the heads of some of the smaller streams dams have been constructed, and, as logging operations are extended further into the mountains, dams will be increasingly necessary.

SILVICULTURAL CONDITION OF STANDS LEFT.

The only regulation as to what trees in the stand should be cut that has been operative is the ten-inch stump-diameter limit, and this has not always been observed. In a mature pure spruce stand, there may be only a few trees per acre below ten inches and when these have been left after logging, they are in great danger of windfall, and usually reach that end. Even if they do escape, they are not sufficient in number to effectively seed up the area or to keep the seed-bed in good condition for the germination of the seed. In some stands of moderate-sized timber, the ten-inch limit leaves the area in a favourable condition, but in the vast majority of cases in spruce stands it allows the removal of too many trees.

In pine stands, where the average diameter is usually smaller than in spruce stands, there is ordinarily left a larger number of trees. However, a uniform result over the whole area of a pine stand is usually unfavourable, no matter what proportion of the trees are left. Pine reproduction is obtained most favourably on ground entirely cleared, while under the shade of a fairly dense cover of trees it is difficult for the seedlings to develop, and surface conditions are not usually favourable to the germination of the seeds. Where logging opens up the stand sufficiently to make conditions favourable to reproduction, if the area opened up is a large one, there will be effective distribution of seed only at the edges. In the centre of the area itself, which is out of reach of the seed that may be supplied by the trees at the edge, the trees left are too few to furnish the requisite amount of seed, and they

Photo T. W. Dwight.

Plate 5 Logged-over area showing Spruce and Pine Seed-trees.

are exposed to wind-fall and sun-scald. When enough trees are left to make sure of plenty of seed being distributed over the entire area and to avoid any serious wind-fall, there is too much shade on the ground for proper development of young growth, and the ground cover is too little disturbed by the logging operations to give opportunity for the germination of a sufficient number of seeds. The only favourable middle ground is where fairly dense groups or small stands are left distributed in heavily cleared areas. This result may be obtained in stands where the average diameter varies considerably from one part of the stand to another, but actually is procured on only a small proportion of the cut-over areas.

The effect of logging on the condition of the surface of the ground is important. Of advantage to both spruce and pine is the exposure of bare soil resulting from the uprooting of trees and dry stubs during felling, from the skidding of the logs and from the construction of roads and trails. Of more particular interest to spruce, since pine seeds germinate with difficulty on any kind of covering over the soil, is

the beating down or scattering of moss or other ground-cover, which tends to reduce the thickness and continuity of that covering without actually laying bare the soil. The dragging of logs to the skidway also spreads or uncovers considerable rotten wood, on which spruce seeds may germinate. The density of the trees left also affects the surface conditions. In spruce stands, ordinary logging nearly always opens up the stand too much, leaving only scattered seed-trees, with the result that material such as moss on the surface of the ground becomes dry and forms a loose, dry covering, or the growth of grass or other unfavourable plants is encouraged. In stands where there is a heavy ground-cover, only if sufficient trees are left to partially shade the ground can effective reproduction be expected. In pine stands a severe opening up of the crown-cover is favourable, not only because the seedlings

Photo A. Knechtel

Plate 6 Lumbered Area, showing Skidding Trail. Debris left in Dangerous Condition in Case of Fire.

require a great deal of light for favourable development, but the removal of a large proportion of the trees increases the amount of skidding, &c., on given areas, and therefore lays bare more soil, and increases the area on which seeds are likely to germinate.

BRUSH.

The chief interest in the condition of the brush after logging lies in its relation to fire. Under ordinary logging conditions, the bole of the tree is cut into logs until a diameter of about six inches in the top is reached. The top with its branches is usually left lying as it fell. Before skidding the logs, however, swampers must remove all the branches from them and these branches are thrown aside to clear out skidding trails. In this way, rough piles are made. Few of these piles are in such shape as to allow them to be burned economically and a large proportion of the

brush is scattered too much to permit burning by any method other than burning over the entire surface. However, a great deal of it is held off the ground so that it becomes well dried, and, except where the site is very moist, the brush decays very slowly and at a negligible rate. Even in contact with the ground, it rots slowly, and the mere lopping of branches from the tops and scattering of brush so that it will touch the ground does not recommend itself as likely to be attended with marked benefits. Lumbered areas show slash lying after twenty years in a condition practically as dangerous as five years after logging. The effect of brush on reproduction does not seem to be important. In general it retards it by increasing the thickness of the litter and protecting and stimulating the growth of some forms of ground-cover.

STIMULATED GROWTH.

This phenomenon becomes important in the consideration of the direct benefit to be derived from the growth of trees left for silvicultural reasons in stands being logged. In many cases, the increase in volume during the period that the trees are left yields a reasonable profit on the investment involved. This return is higher than would be realized were the stand merely left standing without any cutting having been done, because the admission of an increased amount of light increases the rate of growth of the trees left.

The different behaviour of various species under these conditions is very marked. In general, the more tolerant the species, the better will it respond to increased light. The branches of tolerant trees remain green well down the stem even in dense stands, although they receive so little light that growth at the time is inhibited. On the admission of more light by the opening up of the crown-cover, the dense deep crown provides the machinery for increased volume production. Spruce, for these reasons, will take advantage of any opportunities for increased growth offered to it. Its habit of growing with a long cylindrical crown and drooping branches makes it show greater and more immediate results from admission of increased amounts of light than trees with wider, more spreading crowns. Fir is somewhat less tolerant than spruce and has more horizontal branches and spreading crown; therefore, it responds less to opportunities that may be offered to it for making more rapid growth. Pine, being a very intolerant tree, loses its lower branches early and when grown in dense stands has only a small crown at the top of the tree. If such trees are allowed to receive increased light, they are unable to avail themselves of it until the crown develops, which takes a long time.

Stimulated growth is the result usually of the opening up of stands by either fire or lumbering. Trees left after a fire are often very isolated and show extreme increases in growth. Four firs left growing on an area fire-swept forty years ago, averaged 0·23 inches diameter growth per decade before the fire and 0·54 inches per decade after the fire—more than double. After lumbering, the advantage to the different trees of the stand is very variable. Some trees may be completely isolated and show splendid increase, or the exposure may check their growth and injure the crowns by sun-scald, &c. Clumps of small trees are often left intact and only a few of them show any benefit from the opening of the stand. The necessity of studying all the trees on specified areas, if an accurate idea is to be obtained of the actual results, is evident.

Three plots were taken in stands logged twenty years ago, leaving fifty to one hundred trees, eight inches to twelve inches in diameter, per acre, and showed the following per cent growth in cubic feet for the two decades both preceding and following the logging:—

TABLE 5.

STIMULATED GROWTH OF SPRUCE.

Species.	Trees left per Acre.	Before Logging.		After Logging.	
		20 years.	10 years.	10 years.	20 years.
Spruce	110	0 83	0 91	0 99	1 12
"	50	0 73	0 69	1 09	1 33
"	70	0 32	0 40	1 31	1 40

In an area of pine type logged ten years ago, with both spruce and pine left, the following data were obtained:—

TABLE 6.

STIMULATED GROWTH OF SPRUCE AND PINE.

Species.	Trees left per Acre.	Before Logging.		After Logging.
		20 years.	10 years.	10 years.
Pine	40	0 61	0·32	0 69
Spruce	20	0 76	1 11	2·74

The pine shows little increase over its growth previous to the logging, while the spruce shows marked improvement, although its first rate was rapid, owing to the comparatively large amount of light that it received in the pine stand, under the light crown-cover of the latter.

These percentages indicate increase in total volume in cubic feet. As the trees are just reaching merchantable size the increase in board-foot contents is still more rapid, and in the value of the material, greater yet.

Method of Study.

Although observations of this phenomenon frequently were made on individual trees, for quantitative results, studies were made on plots one chain square so as to obtain average results. These were located in stands lumbered approximately twenty years ago. Each tree was chopped into far enough to show forty years' growth and the width of each decade's growth measured. The location of the trees on the plots was marked on a diagram to furnish a definite means of checking the influence of the relative location in the stand of very fast or slow growing trees on their rate of growth. The volume in cubic feet at the present and at the beginning of each

decade was calculated and the per cent growth during each decade calculated by the formula

$$p = \frac{V \quad r}{V + r} \times 200$$

The diameter growth was also plotted on cross-section paper.

FIRE.

A splendid opportunity is given in the Rocky Mountains for studying the influence of fire, since conclusions can be drawn from recently burned areas, showing exactly the condition of the seed-bed; from young second-growth, showing the material from which the final stand will be formed; and from mature stands, which started to grow after some ancient fire, and which show the final result of conditions noted in the earlier periods.

The forest fires of this region are notable for their intensity and the completeness of the destruction wrought by them. Some of the reasons for this are connected with the mountainous topography. The steep slopes aid the flames in gathering

Plate 7. Effect of Fire in Dense Stand. *Photo. G. Cruiser.*

headway and the narrow valleys with their high sides create a tremendous draft. The continuous and dense coniferous stands are also responsible. Spruce has the lowest crown and the flames easily rise to the top, but pine usually grows with a more uniform crown-cover, with more trees to the acre and on drier sites and therefore is more susceptible to crown fires. Both species are shallow-rooted and thin-barked, and hence easily killed. Spruce roots are so near the surface that ground fires, which do not directly kill or weaken the trees, burn off enough rootlets to cause them to be wind-felled. In general, burned tracts have very few trees left living, which has an important effect on the character of the succeeding stand.

Fire also reduces the commercial value of the timber on an area over which it has passed, even though the trees are harvested in a short time. A direct reduction is seldom caused in the volume of material that can be obtained from the stand. The damage is caused in two other ways: first, as a result of drying out, the wood checks, mainly in a tangential direction, and this lowers the amount of lumber that can be sawn out; again, in two or three years, the sapwood stains green, which lowers the grade of the lumber or necessitates an entire waste of the sapwood.

Besides killing the present stand, fires burn off the humus and litter on the ground exposing the bare soil. In spruce stands on moist flats this may be accomplished only in patches, or, if conditions at the time are very moist, a continuous layer of humus may be left on the ground. On an area where spruce reproduction was following a recent fire in a fairly satisfactory manner, there being about 600 seedlings per acre, it was found that sixty per cent of the total area had the ground-cover practically intact and no reproduction; fifteen per cent had the top layers burned off and fair reproduction, and twenty-five per cent had the bare soil exposed and uniformly good reproduction. This tendency for good seed-bed conditions to occur in small patches results in the growth of second-growth spruce oftenest in small, dense clumps, instead of the trees being uniformly spaced throughout the stand. In a pine stand where a fire had been of an intensity just sufficiently great to kill the trees without burning or scorching the crowns, fifty per cent of the surface showed the soil burned bare. Such a condition produces a young stand of much more favourable density for rapid development than where a heavier fire produces an overcrowded stand. Bare soil is, particularly for pine, the best seed-bed; and pine seeds germinate with difficulty on any humus layer, even where spruce seeds will start satisfactorily.

The effect on the supply of seed is important also. With pine, a light fire, which merely kills the trees, does not at once affect the seed supply; but, when the cones and tw[illegible]t, the cones open and many fall to the ground as the dry pedicels and twigs a[illegible] broken by the wind. When the fire is hot enough to scorch the trees, the cones open directly and many fall in a short time, thus immediately putting a large amount of seed in a position to germinate. In general, the heavier the fire, the more rapid and the denser the reproduction, since the seeds are brought to the ground more quickly and the soil is more completely exposed.

With spruce, the first effect of the fire is to burn up existing supplies of seed. Spruce seeds are shed in a short period immediately after opening and do not remain in the cones on the trees as do pine seeds. The fire, therefore, burns all these seeds with the humus and also all the young seedlings. If at the same time all the old trees are killed, there is obviously no chance for spruce reproduction, no matter how favourable are seed-bed and other conditions. As a matter of fact the noticeably small proportion of spruce in second-growth stands is directly caused by this disadvantageous effect of the fire. Reproduction of spruce after a fire takes place under two conditions; first, on moist sites where the fire has been light and some spruce trees have been left alive to supply seed, or adjacent to green stands at the edges of burned areas where there may be a resulting stand of dense, pure spruce, since pine is at a disadvantage on account of the large amount of humus left on the ground under these conditions; second, on areas where pine reproduction is predominant, there are usually scattered spruce seedlings which have started either from seed left in unburned patches of humus or blown in from a distance.

In pure spruce stands where fire burns all the existing seed, kills all the old trees, and the absence of pine prevents possibility of reproduction of that species, the grass which temporarily occupies practically all burned-over areas continues as the permanent occupant of the ground and a meadow is formed. Such a meadow is illustrated in Plate 3. Even where there is a small amount of pine seed available, the large amount of humus left unburned on the moist spruce sites makes the seed-bed so unfavourable to pine that the seed fails to germinate. Most of the mountain

meadows are the result of fire, and many are formed after a single fire in the manner described.

Reproduction of poplar follows fires, mainly on the edges of the meadows, which are commonly bordered by this species. Poplar prefers a moist seed-bed, and, on account of the rapid growth of its seedlings, can compete against grass. These stands are seldom extensive. Poplar also seeds in with spruce on moist sites and is found as a minor component of the stand. The largest areas of poplar are found on southern exposures where its presence is due mainly to the ability of its seedlings to develop on sod.

REPEATED FIRES.

When a fire occurs in a second-growth pine stand, if there has been an interval of twenty-five or more years since the fire from which the second-growth stand dates its origin, reproduction will usually be dense, as pine begins to bear cones at

Photo T. W. Dwight

Plate 8—Mixed Stands of Second-growth Aspen and Lodgepole Pine, Resulting from Repeated Fires.

an early age. In a stand younger than twenty-five years, the reproduction may be more or less scattered, and grass will occupy the remaining area. The grass will assume the dominance, if the stand be too young to have an effective stock of seed, or if the second fire is followed by still others. The result is that the areas become mainly grass-land, with scattered young trees. When repeated fires occur in young stands in which aspen forms a part of the stand and in which the amount of seed on the pines is limited, the aspen is at an advantage on account of its sprouting capacity. Most of the aspen stands on drier sites owe their formation in part, at least, to this factor.

When a fire runs through reproduction under ten to fifteen years old, the occurrence of future tree-growth depends on the existence of a portion of the original

Photo T. W. Dwight.

Plate 9 — Witches' Broom on Lodgepole Pine (caused by dwarf Mistletoe, *Arceuthobium canadense*).

supply of seed that was left after the first fire, since usually a complete de-truction of the reproduction is caused by the second fire. Cones may remain which were not opened by the first fire and have been lying on the ground keeping seeds enclosed in a germinable condition. The second fire opens these cones and, although the first reproduction is killed, it is followed by a satisfactory stock of seedlings. In fact, in some cases, the area has been overstocked with seedlings after the first fire and the reproduction following the second fire is of more advantageous density. In the Crowsnest Valley, a fire occurred fifteen years ago and was followed by one nine years later; and the reproduction after the second fire was of just about the right density.

MINOR DAMAGES.

FROST.

All the species in this region are very hardy, so that direct frost damage is extremely limited. Poplar reproduction was found to be killed by frost in some places. The Chinooks, however, increase the danger from frost, by causing very rapid fluctuations in temperature, which may cause damage to even hardy adult trees. No instances of extensive damage in the Canadian Rockies are at hand. In Montana, near the continental divide, lodgepole pine had the leaves and, in some cases, the buds killed. In the latter instance, the tree eventually died as no new foliage could develop. This occurred during a period of very warm Chinook winds, alternating with severe cold. The affected trees were confined to marked horizontal belts, and on account of the reddening of the dead leaves, the name 'red-belt disease' was applied.

SNOW.

The most extensive damage done by snow is in snow-slides. These occur on practically all mountains rising over 1,000 feet above timber-line which have steep wooded slopes below. The slides are usually recurrent, and follow definite paths, being guided by small gullies and clearing a strip on each side of the gully so that an area of 100 feet wide is laid bare. The slides appear to start generally in a basin on the bare mountain side where the snow can collect and where the sun can shine with full strength and start the snow melting. The areas swept over by the snow have a characteristic appearance, with the trees broken off at varying heights up to fifteen feet, or uprooted entirely, and lying in parallel positions with their tops pointing down hill. Reproduction usually occupies the area, as the seed supply is good from the adjacent stands. The ages and distribution of the young trees is irregular, especially where the slides have been recurrent.

Snow-slides have a practical bearing on the management of many stands, since the danger from them will, in many cases, predicate very conservative cutting. Opening up the stand too much and allowing the sunlight in too strongly might start slides in new places, or allow the present courses of slides to be extended much further down the slopes. Where a strip system of cutting is being followed danger from snow-slides should influence the direction in which strips are laid out.

GRAZING.

The damage due to grazing is at present rather limited. Grazing is done on two types of land in the mountains; first, on areas in the foot-hills, which are partially stocked with young tree growth, usually of aspen and pine mixed, with some willow shrubs; second, on meadows, usually entirely given over to grass, in the main valleys farther up in the mountains. Grazing does practical damage mainly on the first

type. The second type has, in most cases, resulted from ancient fires that have killed a pure spruce stand on low ground, and lack of seed-trees after the fire, or repeated fires, have resulted in the occupancy of the area by grass. These meadows are usually bounded by comparatively dense stands, of second-growth pine, or, sometimes, poplar, and the encroachment of the tree-growth on the grass-land is slow. At the same time, grazing animals are not able to cause much damage to the dense second-growth stands, or to enlarge the area of the grass-land.

The other type, where the grass-land is in patches and the young growth is irregularly distributed and not in dense solid stands, is much more subject to damage from grazing animals. It is also in a much better position to become eventually fully stocked with tree growth, since the areas to be seeded up are not in such large units and the pine and poplar, which both become productive seed trees at an early age, are well distributed so that they can seed up the grass areas better where they are confined to the edge. The grazing animals in this type penetrate all through the area occupied by trees and break branches and tops of young trees, and trample down the young sprouts and seedlings. Areas where the value of the grazing is small, and where a valuable stand of trees may be expected if the area be allowed to stock itself fully with trees should be closed to grazing. At present, however, most lands of this class at all attractive to grazers, have been excluded from the Forest Reserve, and, in many cases, are held under grazing leases.

Other forms of damage are caused by insects, porcupines, fungi, and dwarf mistletoe, but they will be discussed in relation to individual species.

SILVICS.

LIST OF SPECIES.

The following species are found in the southern half of the Rocky Mountains Forest Reserve:

Pinus flexilis. . . . . Limber pine.
" *albicaulis*. . . . . White-bark pine.
" *Murrayana*. . . . . Lodgepole or jack pine.
Larix Lyallii. . . . . Lyall's or alpine larch, or tamarack.
Picea canadensis. . . . . White spruce.
" *Engelmanni*. . . . . Engelmann spruce.
Pseudotsuga mucronata. . . . . Douglas fir.
Abies lasiocarpa. . . . . Alpine fir ("balsam").
Populus balsamifera. . . . . Balsam poplar.
" *tremuloides*. . . . . Aspen (poplar).
Betula alba, var. *papurifera*. . . Paper birch.

DESCRIPTION OF SPECIES.

ENGELMANN SPRUCE.

With the exception of Douglas fir, which occurs in much smaller numbers than it, Engelmann spruce is the largest tree of the region, and for that reason is most sought after by the lumbermen. Lumber from it has numerous small, usually sound knots, on account of the large number of branches which remain green low down on the trunk. The crown is cylindrical with lower branches drooping somewhat. The deep crown is also responsible for the rapid taper of the tree compared with other species, since the diameter growth in the lower part of the trunk is better main-

tained than in pine, for example, where the rapid growth becomes more and more limited to the top of the tree near the short crown. Flaring of the butt is pronounced, especially on large trees. The bark is moderately thin 0.3 inch to 0.5 inch, reddish brown in colour and flaking off in scales 1 inch to 2 inches in diameter. The root system has the heavy main roots radiating in an almost horizontal plane, especially in wet soil, and forming a disk six to eight feet in diameter, and from them smaller anchor roots descend vertically. This makes the tree adapted to growth in its favourite moist sites, where aeration in the deeper layers of soil is poor, but renders it liable to windfall if left standing isolated or if fire burns off the anchor roots, to do which only a light ground fire is required. On well drained soil the tree is fairly wind-firm. The maximum size of spruce is in the neighbourhood of 36 inches in diameter at breast-height and 120 feet in height. Average sizes were given in the stand tables. Spruce is the longest-lived tree of the region, except Douglas fir. Four hundred years is about the maximum age. Thrifty growth is maintained up to from 150 to 175 years even in dense stands, but after that age there is usually a decline to a slow rate of growth.

Atmospheric conditions favourable to spruce include moist air, shade, and protection from the periodic, dry, hot winds. Although the region under consideration has a rather dry climate, spruce is nevertheless able to grow under all conditions, and the effect of climatic influences is shown only indirectly in the rate of growth where its extent is impossible to gauge, owing to the joint influence of other factors, such as the character of the soil. The frequent frosts at the higher altitudes, even during the growing season, have a very important influence in checking the rate of growth on the higher slopes.

A moist, well-drained, deep soil is optimum. Thus the best developed spruce is found in the valleys of small streams. On the broad river-flats, the spruce is generally small, owing either to poor drainage or to the soil being gravelly and therefore raw. As slopes are ascended, and the soil becomes shallower and drier, the size of the spruce becomes progressively less.

In tolerance, spruce exceeds all its associates. The contrast with pine, with which it is so often associated, is remarkable. The effect of its tolerance is to give the tree a very deep crown, to enable it to maintain thrifty growth to a high age, even in dense stands, since the crown does not tend to be reduced to a few branches after the height-growth falls off. It also makes a very dense crown-cover, checking the development of volunteer growth, and making the ground surface moist. On the other hand, seedlings and young trees can persist and develop in older stands, especially in stands with large proportions of pine; and although their growth at times may be negligible (the result of too great shading) yet they are able to profit at once by any increase in the amount of light reaching them.

The chief damages to spruce are caused by fungi, wind and fire. Insect damage appears to be rare. The attacks of fungi are limited. Only a small proportion of the sawn lumber from spruce logs has to be culled for rot. Scattered trees can, however, be found in any spruce stand, killed by fungus attacks. The susceptibility of spruce to windfall was mentioned in describing its root-system. In case of fire, spruce trees are very easily damaged, both on account of their thin bark and their shallow roots. Spruce stands are, however, less subjected to destructive fires than other types, due to the characteristically moist condition of the site.

Reproduction.

Seed Production.—Spruce begins to produce seed at about thirty-five years of age and bears heavy crops every three or four years. The cones are borne mainly near the top of the crown and ripen in the summer. The seeds are shed in a short period after ripening. The cones fall during the winter. The seeds are compara-

tively light, and are easily distributed by the wind. Three hundred feet is about the maximum distance for seed to be distributed and 150 feet the limit of effective seeding on a favourable seed-bed.

Development of Seedling. When the seeds germinate, about five to eight cotyledons appear, followed by the first year's leaves, and at the end of the year the seedling is one inch high with a root about three inches long. The seedling at first grows very slowly, and at ten years is only a foot high. Moisture is necessary, and that is the main factor governing the favourableness of various seed-beds. The thickness and texture of the surface material are also important factors since they influence the ease with which the roots can reach the soil and also the ease with which the roots can avail themselves of the water present in the soil.

In virgin spruce stands, reproduction is found mainly in openings, and is then dependent on the humus being well decomposed and less than two inches thick, and on the ground cover being thin and compact enough to allow the seedlings to take root. The surface moisture is usually sufficient on account of both the shade afforded by spruce stands and the moist soils usually associated with that type of forest. The best reproduction was actually found on bare, very moist soil, in one case produced by the grading of a road on a hill-side and in another case by spring floods washing out a steep creek-bank. The uprooting of trees also provides favourable spots for seeds to germinate. The next best seed-bed is that afforded by a covering of compact, well decomposed humus up to one inch and a half thick, over which lies a thin compact layer of moss or of litter composed of needles or twigs.

The almost classical occurrence of spruce seedlings on rotten logs is quite characteristic in this region, and is readily explained by the capacity of the decayed wood for holding moisture and at the same time providing a medium firm enough for the seedlings to take root in.

In clumps of light-foliaged willow shrubs which usually grow on moist ground where there is considerable grass, excellent spruce reproduction was often found. The light shade of the shrubs checked the growth of the grass and the decayed leaves beneath them formed an excellent seed-bed.

The chief deterrents to reproduction are thick, dry litter, which may be found in very dense young stands, or a thick, loose growth of sphagnum moss, which is unfortunately the prevailing condition in spruce stands. The favourable conditions above cited are found usually on only a small percentage of the total ground surface of a virgin forest, and result in the presence of such a small amount of volunteer growth that reproduction beginning after cutting operations must in most cases be the main source of a new stand. In mixed stands, the humus is usually better decomposed, and the quantity of moss in the ground cover is less than in pure spruce type; and thus often they show the densest and most uniform reproduction of spruce.

Fire is with spruce, the same as with pine, the instrument that most effectively produces on a broad scale surface conditions favourable to reproduction. The most important effect of fire, however, is on the supply of seed, and where that is destroyed reproduction will be poor, even though the seed-bed conditions are satisfactory.

Quantitative observations were made both of average and extreme conditions under which reproduction took place and show the relative importance of sever factors entering into the problem.

To illustrate the effect of distance from seed-trees on spruce reproduction in burned-over areas, two strips were run from the edge of a green spruce stand into an area where reproduction was taking place after a fire. The original stand had considerable pine in its composition and the majority of the reproduction is of that species.

TABLE 7.

SPRUCE REPRODUCTION AFTER FIRE.

Area.	Feet from Spruce Stand	Seedlings per Acre	
		Spruce.	Pine
1/100 acre	50	16,800	35,200
1/800 acre	100	6,400	27,600
1/200 acre	200	800	50,000

The following two strips were run in areas removed from a green spruce stand by the distances given. The first shows satisfactory reproduction after fire in pure spruce stands. The second shows very poor reproduction on account of the distance from seed-trees, and the formation of a meadow will be the probable result.

TABLE 8.

SPRUCE REPRODUCTION AFTER FIRE.

Area.	Feet from Spruce Stand.	Seedlings per Acre	
		Spruce.	Pine
1/10 acre	200	880	80
1/5 acre	1,320	55	30

The following three strips illustrate different conditions on logged over areas.

TABLE 9.

SPRUCE REPRODUCTION AND VOLUNTEER GROWTH ON LOGGED-OVER AREAS.

Volunteer Growth per Acre.		Seedlings per Acre.	Remarks
Spruce.	Balsam.	Spruce.	
270		70	Fair volunteer growth with reproduction
1,100		1	Good volunteer growth alone.
270	190		Volunteer growth alone, with balsam dominant

The figures given below were obtained on small plots averaging in area 1/400 acre. The descriptions of conditions on the plots applied in most cases to only a small area, and therefore the figures do not represent average results, but merely show the relative importance of the various factors mentioned.

TABLE 10

SPRUCE REPRODUCTION.

Seedlings per acre.	Plots representing [illegible]
None	Moist site; sphagnum moss 2 inches and humus 4 inches thick.
	Dense stand with ground cover of dry litter.
100	Area burned in early spring; no bare soil exposed.
2,000	Compact moss; humus 2 inches thick.
3,000	Old burn; little bare soil; 1 inch to 4 inches, well decomposed humus.
6,800	Lumbered area with favourable seed bed; 20 per cent of area covered with litter, rest with thin grass; humus 3 inch thick.
8,400	Opening in virgin stand; seed bed covered with thin moss and needles, 2 inches thick, well decomposed.
10,000	Light thinning seed trees and exposing considerable mineral.
20,000	Road embankment; soil moist and 50 per cent washed bare.

In general, spruce is a tree to be very favourably considered, especially where it already forms a part of stands which it is desired to reproduce by natural regeneration. It attains a comparatively large size and produces useful lumber. It can adapt itself to most sites. It has a favourable rate of growth which has the special advantage of being accelerated whenever an increase in the space around the tree gives a more favourable opportunity for development. Spruce seeds will germinate under many natural conditions of seed-bed, and the seedlings will develop under the shade of the older trees. The chief demerits of the species are its slow juvenile development, even in full light, and its liability to wind-fall.

LODGEPOLE PINE.

Locally, this is commonly called jack pine, but the true jack pine (*Pinus Banksiana*) does not enter the region under consideration. Lodgepole pine is the most abundant tree of the region. In mature stands, it divides the area with spruce and other species, but in the widespread second-growth stands it vastly predominates and so holds a very important place in relation to the future. It also has the distinction of producing the clearest and highest grade of lumber, although it is small in size. This is due to the form of the tree which has a long cylindrical bole, well cleaned of branches, and a small short crown induced by the intolerance of the species and its habit of growing in dense, uniform, even-aged stands. The bark is very thin, 0·2 to 0·4 in. comparatively smooth, with small scales or shallow ridges, and greyish in colour. The main roots descend diagonally into the ground and for supporting purposes do not form a circle of more than four to five feet, and, although they are well anchored by smaller roots, the tree on well-drained soils is little more windfirm than spruce. Its dense habit of growth forbids the exposing of single specimens or small groups to the winds. The average maximum size is about 26 inches in diameter at breast-height and 110 feet in height. In age it seldom reaches over 250 years, and after 125 years shows only slow growth.

Atmospheric conditions affect it more readily than spruce, and the frequent frosts at the higher elevations are undoubtedly a large factor in checking its growth there. In Montana an extensive killing of foliage and even of entire trees was observed as a result of severe and sudden alterations of 'Chinooks' and cold waves, which is illustrative of the sensitiveness of the tree, since other species for the most part escaped apparent injury. Indications of a similar damage to this species in Canada also have been noted.

Pine prefers a dry to a wet soil, but, as in the mountains only the very bottoms of stream and river valleys are very moist, there is only a very small area of soil unfavourable to its growth. On the thin, rocky, dry soils of the upper slopes there is a correspondingly small development of the individual trees and a large number of trees per acre, and also an increasing liability to windfall.

Although lodgepole pine is among the least tolerant trees of the region, its intolerance is sometimes overestimated. Its shade-enduring ability is great enough to allow over 200 trees 80 feet high on one acre to participate in the main crown level at maturity. Among the pines it ranks near white pine in tolerance and is much more tolerant than eastern jack pine, red pine or yellow pine. In this region the trees less tolerant than the lodgepole pine are [illegible] pine, Lyall's larch, balsam poplar, aspen and paper birch. Compared to [illegible] however, lodgepole pine is very intolerant, and the form of the tree, with its clean, slightly tapering bole, and short, small crown, bring this contrast out. Seedlings of lodgepole pine do not develop with great readiness in virgin stands, although [illegible] grow in openings or in stands partially thinned out by ground fire. Young seedlings or trees have considerable power of recovery of growth after suppression, though not as much as spruce, and the larger trees, especially when grown in rather dense stands, show very slight capacity for 'stimulated growth.'

Pine is more susceptible to damage than spruce, not only from fires, but from other agents as well. Insect damage seems to be limited, although occurrences of Dendroctonus beetles have been noted.

Fungus attack is common in some localities, although never on more than a small proportion of the stand. The fungus turns the heart-wood reddish with white flecks, and makes it soft and punky. This rot may occur at the butt or sometimes only in an upper portion of the bole, so that the fungus probably gains entrance through a wound on the trunk of the tree. Fruiting bodies of the fungus are uncommon and the species was not determined.

The most destructive influence in many places is the dwarf mistletoe (genus *Arceuthobium*). This is a small branched plant about 1 in. to 1½ in. long with minute leaves. It grows in colonies on the younger portions of the tree and causes malformations known as 'witch's brooms.' Its more serious effect is the killing of the growing layer of the wood; eventually an area of dead wood is thus left exposed, and these areas are thought to be the main sources of entrance to the fungi. The mistletoe directly deprives the tree of some of its nourishment, and with the aid of the fungus may finally bring about the death of the tree. A mature pine stand was found with 80 per cent of the trees dead, and mistletoe had contributed largely and had probably, in nearly every case, been the initial factor in bringing about the result.

Widespread wind-fall of pine is uncommon, although on the higher slopes a considerable proportion of the stand may be thrown.

A minor cause of damage is porcupines which eat off in patches the bark near the base, or sometimes high up on the trunk, and where the area is extensive enough to girdle the tree, the latter may be killed.

In general, pine is here very sound, and few logs and small amounts of lumber need to be culled for defect.

Reproduction.

Seed Production.—The manner of seed production is one of the most important of the individual characteristics of lodgepole pine. It is distinct, not only from the other genera but also from other species of pine, except jack pine. The main points of interest are: first, the early age at which seed production begins; second, the quantity and comparative regularity of production; third, the persistence of the cones on the trees; fourth, the slow release of seeds from the cones, resulting in an almost permanent locking up of a considerable proportion of the seed; and finally, the long retention of germinative capacity by the seed.

Plate 10 Limber Pine. *Photo A. Knechtel.*

Cones containing germinable seeds were observed to be first borne by pine trees at nine years, and at any age up to twenty-five years. The best production of cones is between thirty and sixty years and continues as long as the tree has a vigorous, well developed crown, but falls off in dense stands when the crowns become narrowed in, and the height-growth falls off. The number of cones produced each year is not excessive, although production in moderate amounts takes place nearly every year. The noticeably large numbers of cones on the trees do not indicate an extraordinarily heavy annual production, but are the result of the persistence of the cones. The cones have short thick stems firmly imbedded in the wood of the branches, and, when cones do fall, it is usually after the stem has been torn from the wood, and not from a breakage of the stem near the cone. The cones will thus remain on the tree for an indefinite period, certainly, in extreme cases, as long as fifty years.

Nearly all the cones contain a considerable number of seeds, but the average is only one sixth to one quarter the total number of scales. The sterile scales are mostly at the base, with a smaller number at the apex also without seeds. The cones have thick woody scales with enlarged apices which fit accurately together when the cone is closed and form a water-tight surface. The heavy scales are, in general, slow to separate. Those at the apex separate first, while those at the base practically never separate, but they also seldom bear seeds. The shedding of seed is variable, since it is dependent upon the opening of the cones, which is influenced by several factors. The average amount of seed shed naturally is only imperfectly known. It is generally agreed, however, that enough cones open every year to furnish a satisfactory supply of seed, although the annual distribution is not as great as with spruce. The opening of the cones is not confined to the period immediately after ripening, but may occur at a later period or be repeated at various times. The seeds are heavier than spruce seeds and are carried only about 150 feet by the wind, and effective seeding extends only about 100 feet. The fall of cones to the ground supplements the direct shedding of seeds, and the transportation by squirrels, &c., of the fallen cones and of cones that they have cut off is a minor agent of distribution.

A factor opposite in character and almost equal in importance to distribution is the storing of seeds. Many cones do not open at all, and most do not open sufficiently to allow the escape of all the seeds, so that on every tree there is a considerable store of seeds. Most of these are eventually wasted by the cones rotting on the ground with seeds still in them, either after falling from the tree during its latter years, or being brought to the ground by wind-fall of the tree. The remarkable persistency of germinative power in seeds is important since the seeds seldom lose their germinative capacity during the period that they are held in the cones on the trees. Seeds from cones, in one case 45 years old, and, in another, 75 years, have been known to germinate.

Development of the Seedling.—The cotyledons are variable in number and are followed by a cluster of whorled leaves. Later in the first year leaves appear which have the normal arrangement in bundles of two. The seedling is about 1½ in. high at the end of the first year. At five years it has reached a height of 18 in. and is over 3 feet high at ten years. No opportunity was afforded, on account of the wet season, to determine how much moisture was necessary for germination, although it was evident that the presence of considerable moisture was favourable. The uniform distribution of seedlings on tracts seeded up in previous years, where large areas of mineral soil had been exposed, argues that sufficient moisture to allow the germination of most seeds is seldom lacking.

The vast majority of pine seeds actually germinate on bare soil, although they will also start on a firm, compact ground-cover of humus, moss, or thin litter, not exceeding one inch in thickness.

In virgin stands, good reproduction of pine is seldom found. The reason is that, even where openings have been formed that admit enough light for the germination and development of seedlings, yet there has been lacking any influence which would

disturb the compact ground-cover sufficiently. Volunteer growth is, therefore, sparse, in most stands, and thickest on the upper slopes where the ground cover is thinnest, and where, on account of the low average height and small crowns of the trees, the light intensity beneath the trees is greatest. Even where pine forms 90 per cent of the stand the majority of the volunteer growth is composed of spruce or balsam.

The various forms of damage that may affect the stand usually promote reproduction, but none except fire is productive of great results in aiding the starting of pine seedlings. A light ground fire will usually afford an opportunity for seedlings to start under the old trees, and the heavier the fire, the closer does the result approach the formation of a dense second-growth stand. The next most effective agent is snow-slides, but the area passed over by them is often covered more readily by spruce and alpine fir ('balsam') reproduction.

Detailed observations of pine reproduction under various conditions were made in the same way as with spruce. With pine, useful figures were obtained only on burned-over areas. The connection between the detailed conditions described here and the general character of the fires and the burned stands have been discussed in a previous section.

TABLE 11.

PINE REPRODUCTION.

Seedlings per acre.	Strips representing average conditions.
380	Too heavy fire; in small second growth timber; crowns and most of seed burned; seed-bed good.
500	Light fire at edge of burned area; soil not sufficiently exposed for pine reproduction and also parent stand largely spruce; 12,000 spruce seedlings per acre on account of seed bed favourable to them, and of proximity of spruce seed trees.
832	Double burn in pine and spruce type; fires 7 and 14 years ago; present reproduction from seeds in cones left lying closed on ground after first fire.
2,200	Continuation of strip having 500 seedlings further away from edge of burned area; fire heavier, exposing more soil; only 700 spruce seedlings on account of greater distance from seed trees.
4,600	After fire in pine slope type; 50 per cent ground grass-covered.
5,850	Continuation of strip with 832 seedlings. More pine in parent stand.
7,280	After fire in pine slope type; 25 per cent ground grass-covered.

Seedlings per acre.	Plots representing maximum conditions.
740	Too heavy fire in small second-growth; most of seed burned.
5,000	Light ground fire; 60 per cent humus unburned; large timber.
6,400	Thin moss on area burned 7 years ago, leaving part of humus unburned.
6,800	Loose grass under same conditions.
15,000	Heavy ground fire; 40 to 50 per cent humus unburned; small timber.
15,600	Crown fire; 30 per cent humus unburned; large timber.
29,600	Crown fire; 30 per cent humus unburned; small timber.
60,000	Crown fire; ground burned bare; small timber.

Lodgepole pine is a tree with many points in its favour. The enormous quantity of it in the present stands, especially in the immature ones, and the readiness with which it reproduces on areas burned over necessitates a careful consideration of its qualities. It produces a very good quality of lumber, and on account of its very rapid growth in early life, it is the tree to be counted on to produce the smaller classes of materials, such as posts and mine props. Its individual characteristics demand for it different silvicultural treatment than for spruce, but it is a tree which will show good results under proper management.

DOUGLAS FIR.

Trees of this species are found in this region in two conditions: first, as largely developed, usually rather open-grown remnants of a former Douglas fir type on the lowest forested slopes; second, as minor constituents of mixed stands dominated by spruce where the fir have usually a small average diameter, and the long slender boles and small crowns of densely grown trees. It is the third most important tree commercially, but the total volume cut falls far below either spruce or pine. Douglas fir has a rather clean bole with considerable taper, especially in the trees of large diameter. The crown has a spreading habit with large horizontal branches and is only moderately deep. The bark is extremely thick, which has a most important influence in protecting the tree from fire. It averages at the stump 1 in. thick for 12 in. trees and 2½ in. for 24 in. trees. Its root system goes deeper than any other species, but is adaptive. The tap root is usually well developed and in open grown trees on deep soil, there are two or three other strong, deep roots.

It also develops lateral roots, and in shallower soils these form the main part of the root system. The tree is, however, always wind-firm. Its maximum size is about 48 inches in diameter at breast-height and 130 feet in height. In the mature Douglas fir type, the diameters range around 24 inches and in the mixed type around 15 inches. Its maximum age is about 500 years and the period of thrifty growth in dense stands is up to 200 years.

Douglas fir is not favoured by a moist atmosphere, as is spruce, and its preference for lower altitudes would indicate a sensitiveness to low temperatures, although it is occasionally found extending up to timber line.

A deep, well-drained, loamy soil is an optimum one. The tree is also found on drier shallower soils but not much on very moist sites.

It falls into the class of tolerant trees, but its demand for light is greater than that of either spruce or alpine fir ("balsam"), as is indicated by its shorter crown. Its tolerance is, however, sufficiently great to allow it to hold its place in a selection forest, and to show a good increase in growth when light is admitted to the stand.

The chief damage to Douglas fir is caused by fungus attack which produces rotten heart-wood. The tree is very resistant to both wind and fire damage on account of its deep root-system and extraordinarily thick bark. These factors are responsible for the present existence of a large proportion of the trees now to be found, especially where they hold isolated positions or form park-like stands on areas run over several times by fire which caused the death of all the other species, and often of the smaller firs. Douglas fir stands are the only ones in this region in which fire, as a rule, destroys only a portion of the total number of trees.

Reproduction.

Douglas fir reproduction follows similar rules, practically, to those for spruce and would respond favourably to any measure that would secure reproduction of the latter species. Cones are borne intermittently and the seed is shed soon after ripening and carried comparatively easily by the wind to distances somewhat less than spruce. Germination and development of the seedlings are favoured by the same factors as in spruce but will take place on less favourable surfaces where the ground is drier, the humus thicker or the ground-cover denser. Douglas fir is the most aggressive species to seed in on a grass-covered area. The isolated individuals on the borders of the prairie are usually surrounded by seedlings originating from their seed. Spruce under the same conditions succeeds in establishing young growth only to a comparatively short distance.

Practically no opportunity was afforded to study the direct effect of logging operations on fir reproduction since the few trees which formed part of the stands being logged were generally of a merchantable size and were consequently removed.

Fire is, on the average, followed by more reproduction than in the case of spruce, on account of the larger number of Douglas fir that survive a fire. The seed-bed conditions induced by the fire are equally favourable to those found after a fire in a spruce stand, unless occupation of the ground by grass has been more or less advanced. In the latter case the grass roots may survive the fire and the growth of the grass be resumed before the seedlings have a chance to start.

Where forming a portion of present stands, Douglas fir should be given at least equal consideration with other species. On account of the relatively small amount of it, however, it does not constitute a very important problem from the standpoint of natural regeneration. Whenever planting is contemplated, it is a most important species to be considered. The seedlings can successfully compete with grass, and, when they reach a large size, are safer than any other species from wind-fall and fire.

ALPINE FIR OR 'BALSAM.'

This is the third species in order of number and fourth in order of merchantable volume. It is short-lived and defective and its timber is knotty and soft, and warps badly, and hence the tree does not rank high in popular estimation. Its chief claim to consideration is in relation to the silvicultural effect of its presence in a stand, and that is generally unfavourable. It resembles spruce in having a deep, cylindrical crown, with a conical top, but it has more horizontal branches. The bole is somewhat cleaner, and more cylindrical, without any flaring at the butt. The bark is very thin, and resembles eastern balsam fir in its smoothness, light colour, and blisters. The tree is rather firmly rooted. A considerable portion of wind-thrown trees are broken off a short distance from the ground because of rotten heart, while the roots are not disturbed. The maximum size of alpine fir trees is about 18 inches diameter and 90 feet in height, but the large majority are below merchantable size. The ease with which alpine fir falls a prey to various forms of damage prevents it usually from reaching a great size or age, and from dominating the type of forest except in restricted areas. Like spruce, it is favoured by moisture both in the air and the soil, but nevertheless grows on the dry, thin soils of upper slopes, and is the most common secondary species in pine stands. It is a very tolerant tree but slightly less so than spruce. Its seedlings bear long suppression and the volunteer growth is often stunted and with a horizontal axis.

Reproduction.

The chief point of interest in relation to alpine fir reproduction is its superior ability to reproduce in virgin stands, because that has resulted in the existence of a larger stock of volunteer growth of the alpine fir, or 'balsam,' than of any other species. Seed production and reproduction from seed take place in substantially the same manner as with spruce, and in general with about the same quantitative results. Alpine fir has an additional aid to increase in its numbers in the ability of branches that come in contact with the ground to take root. A vertical shoot starts growing at that point on the branch, and eventually this becomes an independent tree. Many of the suppressed alpine fir in virgin stands are bush-like in character, and have branches down close to the ground. Reproduction by means of 'layering' is therefore common.

After lumbering, aggression by alpine fir is due to the further development of existing volunteer growth, rather than to the starting of new seedlings. The surface of the ground, after the stand is opened up by logging, probably becomes too dry for alpine fir reproduction.

On account of their small size and thin bark, most of the alpine fir are killed by any fires that may occur, so that reproduction of this species after fire is usually

comparatively unimportant. However, second-growth stands of spruce regularly show a minor proportion of alpine fir trees, since the conditions which result in spruce reproduction also favour alpine fir, although the latter species is at a disadvantage.

WHITE SPRUCE.

This species reaches the southwestern limit of its range on the east slope of the Rockies. It is found mixed with Engelmann spruce at the lower elevations, and does not usually ascend the higher slopes. It occurs, especially, in the larger river-valleys and in the stands of spruce near the prairies. It forms but a small percentage of the large bodies of spruce timber and from a commercial or silvicultural standpoint does not need to be distinguished from Engelmann spruce, as the form and size of the tree, the quality of the timber, and the habits of growth and reproduction do not differ to any practical extent.

Plate II Whitebark Pine (dwarfed by exposure to winds and frost). *Photo A. Knechtel.*

LIMBER AND WHITE-BARK PINES.

These two species of pine are found as scrubby trees on the poorest sites. Owing to their infrequent production of cones and the difficulties involved in distinguishing them, the exact occurrence of the two species was not determined. It is probable that white-bark pine alone occurs on the higher ridges in the mountains proper, and that limber pine is mainly confined to the higher elevations in the foothills. Neither species reaches merchantable size except occasionally, nor is of great importance from the standpoint of forming a soil-cover on poor sites, since they

are not aggressive enough in natural reproduction to bring about much practical benefit.

Limber pine, under favourable conditions, reaches a size of 18 inches diameter and 60 feet in height, but even then is very subject to having forked to old crooked boles. Most of the limber, however, and all of the white-bark pine are stunted, and on exposed sites are reduced almost to creeping shrubs. The root system is rather shallow and the trees are subject to wind-fall, although mainly on account of the shallow soil and exposed site which they habitually occupy. Their capacity for resistance to climatic extremes is very great, as they are nearly always subjected to frequent frosts, and severe storms. Their tolerance is small, and probably less than that of lodgepole pine, and this factor is to a considerable degree responsible for their not extending their range to lower sites. The amount of cone production is very small in this region and is the main reason for the small number of trees of these species. As the seeds are large, they will germinate on a moderately thick humus as well as on mineral soil.

LYALL'S OR ALPINE LARCH.

This species is confined very closely to the area next to timber-line, although sporadic individuals may be found in mixed stands lower down. The largest tree observed was 17 inches in diameter by 90 feet in height. Usually it is of stunted growth, reaching a diameter of 7 to 8 inches and a height of 40 feet. The presence even of a single tree is made conspicuous by its light-coloured foliage. It never forms stands of any large extent and is worthy of only casual interest. The bark is very thick, approaching, in this respect, Douglas fir. On a 17 inch tree it was 1¼ inches thick. When it develops to timber size it has a long, clear bole and short crown. It is rather deeply rooted. It is the most intolerant of the conifers, which makes reproduction of the scattered individuals in dense mixed stands difficult. Reproduction of the trees near timber-line is also poor on account of the severity of the climate and the raw humus covering the soil, which is unfavourable to the germination of the small larch seeds.

BALSAM POPLAR.

This is the largest hardwood of the region. It grows only near creeks and on moist flats, and is usually associated with spruce. It reaches a diameter of 30 inches and a height of 90 feet, but the large trees are nearly always rotten at the heart, so that the tree is little thought of from the standpoint of wood production. It has a clean bole, broad spreading crown, and shallow root-system. It is intolerant, but less so than aspen, and on account of its rapid juvenile height-growth is able to hold its place when starting with spruce. It reproduces only on moist, bare or lightly-covered soil, and the only condition under which wide-spread reproduction may take place, is after a fire on a moist spruce site when it may seed in on an area previously unoccupied by it. Its frequent occurrence at the edges of streams is probably due in part to the excessive washing of the soil there which exposes patches of mineral soil that have the requisite amount of moisture for the development of poplar seedlings.

ASPEN.

Unlike balsam poplar, aspen is found mainly on dry slopes, especially on the edge of the prairie where repeated fires have destroyed the coniferous growth. Aspen owes its occupancy of these areas to its rapid growth as a seedling, which lets it compete with grass, and to its sprouting capacity, which provides for a new growth

Plate 12.—Balsam Poplar. *Photo A. Knight.*

Plate 13—Second-growth Aspen. *Photo D. B. Dowling, C. S. C.*

even when a fire runs through an area of reproduction. Most of the aspen, at present, is second-growth and immature and trees over 8 inches in diameter and 50 feet in height are infrequent. It is very intolerant, more so than any species except perhaps paper birch or alpine larch. It reproduces best on a freshly burned soil, which should preferably be moist. It is the most aggressive species on the edge of grassland, but makes appreciable headway only when fire temporarily kills off the grass. It is nearly always found as a fringe on the edge of meadows in second-growth pine stands, where the moist seed-bed and its rapid seedling growth favoured it rather than pine. Its ability to coppice, even when very young, gives it an advantage over pine in struggle for the occupancy of areas subject to repeated fires. Reproduction only three feet high will, after being killed by fire, be followed by coppice-shoots from the stems and roots. The starting of coppice growth from the roots of living trees also gives aspen a chance that is not possessed by other species to make headway against grass.

PAPER BIRCH.

This is a very uncommon species in this region and was only once observed on a snow-slide not far from timber-line in the region of the Bow river.

METHOD OF STUDYING REPRODUCTION.

The method of studying reproduction outside of the making of general observations was to count, on definite sample areas, the number of seedlings, which would afford a basis for quantitative comparisons, and at the same time to make a complete and careful description of the conditions of the area, emphasizing the points of special influence. The description was made according to a schedule covering the following points: elevation, slope, aspect and site quality, type and proportions of different species, age, density and condition of stand, light admitted to plot, seed-trees and cones, undergrowth, ground cover, humus and soil. The reproduction was divided into three size-classes, viz., (1) up to 6 in., (2) 6 in. to 3 ft., (3) 3 ft. to 10 ft. Two kinds of sample areas were taken: first, to show optimum or extreme conditions of any kind, plots 10 ft. square, in area approximately 1 400 acre; second, to show average reproduction under certain widespread conditions such as those resulting from a fire or lumbering, strips $\frac{1}{4}$ or $\frac{1}{2}$ chain in width and up to $\frac{1}{4}$ mile in length. The small plots allow the making of very accurate and definite descriptions of the factors influencing reproduction and are most useful when taken in places where there is reproduction of from one to five years in age. Strips may be taken in areas where the reproduction is any age below that at which seedlings begin to die as a result of crowding, but are also most useful where the seedlings are very young.

MANAGEMENT OF TIMBER-CUTTING OPERATIONS.

SILVICULTURAL METHODS.

In suggesting methods to be followed in regulating the cutting of timber in this region, it must be emphasized that the two main species, spruce and pine, are, with respect to silvical habits, for the most part diametrically opposed, and yet are growing frequently in intimate mixture. The treatment of stands will therefore vary radically according to the preponderance of one or the other species. In mixed stands, the decision to favour one species at the expense of the other must frequently be made before a plan of operation is settled upon, because measures which may be adopted to favour reproduction of one species will frequently be inimical to the other. The discussion of the methods of handling pure stands of each species will bring out most of the essential points to be considered, and the discussion with regard to mixed stands will be confined mainly to pointing out possible compromises and the relative advantages of operations that might be carried out under various conditions.

PURE SPRUCE TYPE.

This is found mainly on the better sites (I and II) and possesses on each site similar characteristics, showing, however, greater variation in the sizes and ages of individuals as well as a greater maximum size, on deep, moist soils; and also showing a heavier ground cover, usually of moss. It has been pointed out that under ordinary lumbering practices the spruce stands are generally opened up very heavily. Scattered trees are left, many of which are windthrown in a short time, especially as the trees that are naturally the ones to be left are of comparatively small diameter and of great proportionate height; and the number of them is insufficient to effectively seed up the area or to keep the ground surface in a favourable condition for the germination of seed. As a result, progress toward a replacement of the old stand by young growth is slow, and in many stands where the logging was done as much as 25 years ago, little reproduction has taken place.

As improvements in the methods of removing the timber, two systems suggest themselves. Both would make a radical change in this particular respect, that a large portion of the existing [illegible] would be left for future cutting. Such a proposal is entirely defensible on the [illegible] and that the stock of timber in the forest reserve will become increasingly inadequate to supply the demands that will be made upon it by the growing population on the prairies, and at the same time will become commensurately more valuable. Therefore, aside from the silvicultural benefits gained, it is a profitable investment to reserve a portion of the stand in a quantity sufficient to make it a practical proposition to log that portion separately at a later date.

The first system is to cut the timber clear in narrow strips, not over 100 feet wide, leaving an equal area of timber uncut in alternating strips. The second cut should not be made for at least thirty years, under no circumstances until the first cut-over area had seeded up, and preferably not until the young trees there were bearing cones abundantly. This method gives the best security against wind-fall when the strips are kept narrow and are skilfully located, and it will be chosen in many cases mainly because protection from this danger is desired. It has the disadvantage of leaving the ground entirely bare of large trees during the period of reproduction, and, as during the juvenile period the development of spruce is very slow, there is practically no volume increment and the area is kept unproductive for a considerable period.

The second system is the selection system; and this, if followed, must be practised conservatively on account of the danger from wind fall. On an average, thirty per cent of the merchantable stand should be left, but the exact amount will vary in different stands, depending mainly on the range of diameters. That will also be an important factor in deciding between this system and a strip system, the latter being chosen where the trees are more uniform in size throughout the stand. The selection system must be operated by marking each tree to be cut. These will comprise the larger trees of the stand, but no definite limit should be set, and one of the chief aims of the marker should be to leave a uniform stand on the ground, rather than to remove all the trees above a certain size. The advantage of the system would be that, while reproduction was taking place on the ground, there would be trees left that would occupy a portion of the growing space without materially retarding reproduction or the development of the seedlings, and the older trees would, on account of increased light afforded them, grow at a rapid rate. Many of them, also, would grow from a size so small that harvesting them would yield a small proportion of the total volume of the tree as lumber of poor quality into a size which would give fairly good lumber with less proportionate waste. The spruce seedlings would thus be given an opportunity of passing through the period of slow growth without exclusively occupying the area and having it for that period comparatively unproductive from the standpoint of volume growth. Also, the shade afforded by the trees left would keep the seed-bed moister, but on the clear cut strips, the concentrated logging would expose more mineral soil and aid seeding in that way.

PURE PINE STANDS.

Most of those that are now being cut are even-aged, with few relatively small trees. This makes a system of clear-cutting advisable, since there are few trees which can, because of their small size, be left economically, and the stimulated growth of the trees left would be small after the stand was opened up, as pine in dense stands has a small crown and slight power of recovery.

The best method of clear-cutting is in strips, which should be 100 ft. to 250 ft. wide with 100 ft. to 150 ft. left uncut in between, the exact widths depending on the proportion of timber that it is desired to remove at the first cut, and on the danger from wind-fall. The strips do not need to be laid out mathematically, but should be distributed according to variations in the size of the timber and according to topography. The smaller and more elevated trees should be left, the latter because of the better distribution of seeds from high points. This method provides a full supply of light for germination and development of the pine seedlings, and gives a maximum preparation of the seed-bed. The distribution of seed over the cleared area should also be satisfactory, if the distances given are adhered to. The second cut should not be made until the young growth on the first-cut strips is old enough to seed back, which would be at least twenty-five years. That means that the two logging operations by which the timber would be removed would be entirely distinct as far as practical business considerations are concerned.

The splendid and often too abundant reproduction of pine after forest fires suggests using that instrument to secure reproduction on clear-cut areas, where, after the logs had been removed, the brush might be burned broadcast. The idea is attractive and will probably eventually prove of practical utility, but at present practical considerations prevent its use being recommended, at least until greater experience in burning brush is gained. Forest fires occur only under drouthy conditions, and to set fire to brush under the same conditions would be very dangerous. Under conditions moist enough to make the measure comparatively safe, practical difficulty would probably be experienced in getting the ground uniformly burnt over, and the expense would be proportionately great. Moreover, the chance of successful repro-

duction would not be as great as in the case of a regular forest fire because the cones after logging will all be borne on the brush which is lying on the ground, and, when the brush is consumed, the cones will be mostly burned so hard that the seed will be killed. It is the moderate scorching of the cones which opens them and causes them to fall to the ground; that is the main factor in making such a large number of seeds available for reproduction as is usually the case after an ordinary forest fire. It may be found advantageous to make use of fire, mainly for the purpose of preparing the seed-bed, where the seed itself will be supplied from trees left uncut, as in the strip system. Considerable difficulty in carrying out the operation of burning under these conditions must be reckoned on.

Some pine stands are uneven-aged, usually in consequence of the occurrence in the past of light ground fires which have partially opened up the stand and allowed the development of young trees under the old. In such cases, a selection cutting may be made, removing the old trees which are often damaged, and leaving the young. The latter will have thriftier crowns than the small trees of a more even-aged stand, and so will make profitable growth after the removal of the larger trees.

MIXED STANDS.

Mixed stands, where pine predominates, may be cut according to systems similar to those used in pure pine stands. In leaving uncut areas, those should be chosen which contain most spruce, unless the spruce are of a very large size. This is because spruce will show faster future growth and is not so liable to deterioration. Further, since the seed-bed cannot often be radically altered from the natural condition, denser reproduction will probably be obtained by having spruce seed-trees left.

When the stand shows fifty per cent or more of spruce, the system of cutting should approximate the selection system, although cutting small groups clear would be permissible. Young thrifty spruce will be most profitable to leave, both on account of their capacity for future growth and of the greater ability of their seeds compared to pine to germinate on the seed-bed of the natural forest floor. Skidding should expose enough mineral soil to allow pine reproduction, especially where groups are cut clear, and therefore it will be proper to leave pine with the spruce. The main object will be to protect the trees left from wind-fall, by leaving them uniformly distributed or next to openings in dense groups. The person doing the marking will be required to study the detailed conditions of each tract of timber and vary his methods a great deal according to his judgment of the demands made by those conditions.

Large mature spruce will be the trees most necessary to remove, since they have a fairly slow rate of growth and are in great danger of wind-fall when the stand is opened up.

The attitude that should be held toward other species than spruce or pine which may enter into the composition of the mixed stand has been pointed out in the discussion of the silvical characteristics of the individual species. They seldom form a very large percentage of the total stand, and therefore their presence would not greatly influence the general method of treatment determined upon after a consideration of the relation of the two main species.

MARKING RULES AND METHODS.

Marking consists either in designating each individual tree for felling or for reservation, or in designating areas for the same purposes when a system of clear-cutting is being followed. In the latter case, all that is necessary is to blaze a line of trees as a boundary with some distinctive blaze that will avoid confusion with trails, &c. A notch above and below the blaze would fulfill this purpose. The trees

marking the boundary would not be cut. When the trees for cutting are selected uniformly from the stand, the general practice is to mark each tree to be cut. A blaze is made at breast-height and another below stump height. Fellers are instructed to leave the latter blaze showing after every tree is felled, otherwise the penalty for cutting unmarked trees is imposed. However, when snow is deep, the tree can often be marked only at breast-height. It is best to stamp each blaze with a distinctive mark, and for this purpose, special marking axes are used, which have a die on the head of the axe. When the trees to be left are small in number relatively to the trees to be cut, the former are sometimes marked. As blazing is liable to cause damage to trees left for a long period, other methods of marking have been used. For instance, in lodgepole pine where the bark is light coloured and smooth, red spots have been painted on the bark. The cost of marking in dense timber is about 1c. to 1½c. per thousand feet, board measure.

In marking individual trees to be removed from a stand, some diameter is usually borne in mind, as indicating approximately the border between trees to be cut and those to be left. This is a matter of convenience rather than an essential factor in deciding on what trees to leave. Usually the leaving of a uniform stand is an important consideration, and then trees well above the diameter limit are left to avoid making large openings or trees below it are cut to thin out too dense groups. The diameter limit is most useful in regulating the marking where a definite proportion of the original stand is to be reserved for future cutting. It is impracticable to estimate the volumes of the trees as they are marked, in order to determine just what proportion of the total volume of the stand will be left. However, by carefully estimating representative sample areas, a diameter limit may be arrived at, which can be easily followed in marking the timber and will operate so as to leave uncut the proper proportion of the stand.

Another important factor besides the size, in choosing the trees to be reserved, is their growth and vigour. This depends largely on the character of the crown which should be comparatively deep. It is especially hard in pine to select trees that will make rapid growth, because, if pine trees have been badly suppressed, their crowns will be very small and their rate of growth negligible. Consideration of this factor might lead one to select for reservation the larger of two trees, if the smaller had been badly suppressed and was growing at a very slow rate. The best trees to leave are those with narrow deep crowns. Wide-crowned trees take too much space and have branchy boles, and short, narrow crowns indicate slow growth.

The trees to be left should be as far as possible sound. Rotten trees deteriorate if left standing and should be harvested as soon as possible, while sound trees increase in value by adding to their volume and give a return on the investment involved in leaving them standing. However, when a tree is so badly decayed that there is not enough lumber in it to make logging it profitable, then it is certainly better to leave it and to obtain the benefit of any seed it may supply.

BRUSH DISPOSAL.

It has already been pointed out that in this region the brush left after logging decays very slowly, and that, even if the branches were lopped from the tops so that they would lie close to the surface of the ground, the brush would remain in an inflammable condition for almost as long a time as though nothing had been done to it. Piling the brush without burning it would aid considerably in fighting fires, but the stands are usually so dense and the amount of debris left after logging so large, that this method would not afford sufficient protection.

It is, therefore, recommended that wherever practicable the brush be burnt. Least labour would be involved in following a method of broadcast burning, but that is dangerous under most conditions and involves practical difficulties not only in

controlling the fire but also in getting the brush completely consumed. Until greater experience has been gained in the actual operations of brush-burning, it would seem advisable to use some surer method. The best way is to pile the brush. The piles may take any form, such as windrows, long rectangular piles, or round piles. They must, however, be of a form that will allow the piling of the brush compactly and to a height of at least four feet. Otherwise difficulty will be experienced in burning the brush. For these reasons, round piles will probably be found the best. The best piles are about eight feet in diameter and six feet in height. Such piles may be burnt when covered with snow up to two feet in depth, and the brush will be practically all consumed. The piles may be lighted most conveniently with coal-oil torches. The burning should be done when there is snow on the ground, the most favourable conditions being found after early snow-storms in the fall. Snow-storms occurring in the spring, after most of the winter's snow has thawed away, give other opportunities for brush-burning. Only under special circumstances should burning be done when there is no snow on the ground, though it may be practicable when the ground is very damp and the piles partially dried out.

Brush may also be burnt while logging proceeds, in which case the swampers start fires and throw the brush on them as soon as it is removed from the logs and tops. This method should prove to be the cheapest and is especially advantageous as the burning is independent of weather conditions and the brush is gotten completely out of the way of the skidding teams. It cannot, however, be practised when the logging is being done at a season when there is no snow, nor on areas where a heavy stand of timber is being removed, because it would be difficult to find places to build the fires on account of the large number of logs lying on the ground.

The cost of brush-burning should be kept between 20c. and 30c. per thousand feet, board measure, and in favourable circumstances can be reduced below that amount. Early attempts in the Rocky Mountains will in all probability run in excess of those figures until the men become familiarized with the actual carrying-out of the operations. An expenditure of at least 40c. should be allowed for at the start.

COST OF SILVICULTURE.

The cost of the changes from the ordinary methods of lumbering which have been suggested can only be estimated in a general way, as the exact amount depends on the detailed conditions of each operation. In some cases, the cost of logging will be very little increased, because some of the operations, such as brush-disposal, tend to reduce the cost of removing the timber. A constant influence toward increasing costs will be experienced from certain factors. When a selection system of cutting is being followed, the cost of felling and skidding will be increased because the trees must be removed from among the others that are left standing. In any system where a considerable proportion of the stand is reserved for future cutting, the cost of road construction per thousand feet is proportionately increased, because if the area were clear, the cost of the roads would be distributed over so much more timber. This factor should be possible to calculate ahead of time with reasonable accuracy when the details of a prospective operation are known. The cost of supervision, marking and brush disposal are also mainly to be figured against the expense of logging according to silvicultural methods. The total amount, where the methods are followed in an intensive manner, should be in the neighbourhood of $1 per thousand feet, board measure.

CONTRACTS.

A sale of timber may be for a definite area or for a certain quantity of timber. If the area be bounded by rectangular survey lines it may include exactly a natural logging unit, but usually will leave out part of one or take in part of some other

Photo T. W. Dwight.

Plate 14 — Brush Piled Properly for Burning. (Deerlodge National Forest, Montana, U.S.A.)

Photo T. W. Dwight.

Plate 15 — Clearcut Strip after Brush-burning. (Deerlodge National Forest, Montana, U.S.A.)

logging unit. Thus it is better, especially from the point of view of administration in the woods, to use natural topographic features for boundaries. When the quantity of timber to be cut, and not the area, governs the limit of the sale, the general boundaries may be stated in the contract, and the detailed location left to the forest officer as the operation proceeds. The amount of timber may be stated in feet, board measure, if the major portion of it is to be saw-logs, and an average board-foot content laid down for other classes of material that are not readily scaled in board measure. A time limit should be set for the complete removal of the sold timber, but provision may be made for extension of the period for valid reasons. Many sales are made for a year only with provision made for annual renewal on the same terms in case the regulations have been observed. The removal of all improvements and equipment should be required within a prescribed period, say six months from the termination of the contract, subject to the ownership passing over to the government in case of non-removal.

A contract should usually state that only the green timber designated by the forest officer to be cut may be removed. It may then fix a definite percentage of the total volume as a maximum to be reserved, but the selection of this amount should be left to the forest officer to meet in his judgment the silvicultural requirements of the stand. Reservation of a portion of the stand may be made by fixing a diameter limit, which is the simplest in operation, but not as effective from a silvicultural standpoint. When a conservative silvicultural system is to be followed, the buyer must be made to understand in advance the general nature of it so that he can form a judgment as to the extra cost involved in marketing the timber under these conditions. It is usually impossible to lay down in advance in the contract the exact details of the method of cutting to be followed. Where dead timber has a market value, it should usually be required that it be utilized just as far as it is merchantable, and a diameter limit that may be set for green timber should not be applied to the dead.

Regulations as to the cutting of individual trees should specify the maximum height of stumps, and, for lodgepole pine and spruce, may be very satisfactorily stated as not greater than the diameter of the tree, and in no case over 18 in. This rule is at the present time voluntarily followed by some operators. The maximum diameter at which utilization of material in the top of the tree is to cease must be set. This will vary with market conditions and will be largest where only saw-logs can be taken and smallest where there is a demand for cordwood.

The price will usually be fixed according to standard units—board feet, pieces, cords, &c. The scale to be used in determining board-foot contents must be stated. A severe penalty should be imposed for removal of timber previous to measurement. In case of large sales extending over a number of years, provision may be made for adjusting the prices at stated intervals. The basis would probably be the average prices obtained in a specified region in a certain period previous to the time of adjustment.

A penalty, usually the payment of double stumpage, should be imposed for the cutting of unmarked trees. When the latter are damaged during logging, the forest officer may be given authority to require their removal and double stumpage be charged for them. In large operations, a provision that different parts of the work must keep pace with one another is important, especially in relation to protective measures, such as brush-piling.

Of protective measures, the disposal of brush is the most important. Provision should usually be made for either lopping or piling, as the forest officer in his judgment may direct. In practice, scaling is sometimes kept back until the brush is satisfactorily disposed of. The brush-burning may be done independently by the government, but it is better to have an agreement with the buyer by which he will furnish men engaged on the logging operation to assist, even if remuneration for those services has to be allowed.

It is advantageous also to have an agreement with the operator by which his men will be available to fight fires. No remuneration should be allowed when the fire occurs on the area of the sale, or endangers the area directly, but in case the agreement covers assistance in fighting fires not directly connected with the area but within convenient distance, remuneration should be allowed. For fires due to carelessness of the operator's employees, a provision may be inserted in the contract for uniform damages per acre, *e.g.*, $10 per acre, which would avoid disputes in appraising damages, which would be a difficult thing to do especially if destruction of young growth were an important factor.

The vesting of authority as to supervision of the sale, final settlement of disputes and interpretation of provisions of the contract should be definitely included in the contract.

The method of payment depends mainly on existing administrative regulations. Other legal provisions not directly affecting the management of the cutting of the timber form a necessary part of the contract.

SILVICULTURAL PRACTICE IN MONTANA.

DEERLODGE NATIONAL FOREST.

Forest Conditions.

The Deerlodge National Forest is situated on both sides of the continental divide, and surrounding the Butte copper-mining region. It furnishes annually about six million board feet of timber, of which ninety per cent is lodgepole pine. All the timber is used for mining purposes. Logs with a top diameter of 6 inches or more are used in a round state for props; smaller logs, down to 2½ inches in diameter, when straight, can be used for other purposes. There is also a market for cordwood. Under these market conditions, it is possible to require a utilization of all material three inches and over in diameter. The silvicultural effect of this is that where it is desirable to clear-cut an area, the operation can be done thoroughly, because every tree can be cut, and so much material removed from each tree that the brush can readily be burned, leaving the surface entirely cleared.

The type of forest is, predominantly, pure lodgepole pine. In the creek bottoms are belts of pure spruce, usually not over a fourth of a mile wide. On the upper slopes are mixed stands of lodgepole pine, spruce and limber pine. The mixed and the spruce type resemble the types described by similar names when discussing Canadian forests. The pine type differs only in a few minor respects from the same type in the north. It is purer in composition, less even-aged, of lower density and with the trees branchier and more damaged. This may be explained by assuming a different life history. Canadian forests often show evidence of the entire stand having started after a fire, but in mature stands there is seldom evidence of more than one fire. In Montana, fires seem to have been of greater frequency but less severe. The successive fires have eliminated the spruce, except in the two types mentioned, which owe their distinctive characteristics to comparative freedom from fire.

The successive fires have also opened up the stand and allowed young trees to start, but, as pine develops with difficulty under such conditions, the density is made lower in comparison with stands developing from the dense, even-aged, young growth that usually follows a single severe fire. This also results in branchier timber, and the fire-scars on the timber which is not killed by the fires combine to make the trees in general much more poorly fitted for lumber than in Canadian stands.

The condition of the ground surface is radically different in the south. The ground-cover is very thin, consisting usually of about one inch of humus and light litter. The growth of a light carpet of pine grass is common, and this is not found in the north. Thick moss, again, is practically never found on the ground in pine

stands in Montana, whereas it is of common occurrence in Alberta stands. On the whole, there is a better seed-bed for natural reproduction of pine in the south than in the north.

Silvicultural Methods.

The method of leaving seed-trees in blocks was the initial system followed. One hundred and fifty foot strips were clear-cut with a 75 foot interval; and one half of this remaining timber was removed in 75 foot squares, leaving blocks of seed-trees also 75 feet square. This method proved unsatisfactory. Too small a proportion (only 17 per cent) of the timber was left, so that the blocks were too isolated, and severe wind-fall ensued. There was also considerable damage from sun-scald. Three years after the logging was done, sixteen blocks showed an average of 25 per cent wind-fall. The system also did not allow the selection of stands of comparatively young timber to be left, but by requiring their removal forced an unnecessarily large amount of small material on the market.

The next modification was the leaving of blocks of trees in favourable locations to furnish seed to the cut-over areas. The most characteristic example is furnished by narrow gulches, where the lower slopes were cut clear, leaving belts of timber at the top. It has been decided that the areas left were too large.

Most of the cutting done according to these systems was three or four years ago, but at present marked progress toward re-stocking is not apparent. A narrow strip, half a mile long, showed only 185 seedlings per acre, and a quarter-mile strip, 325 per acre. This, of course, is too early to expect marked developments over the whole area, but it was plainly indicated that under any system satisfactory reproduction need not be expected in a short period immediately after logging. Only under conditions resulting from fire has effective reproduction been found to take place in a very short time.

During the last two years, the methods practised have undergone marked changes in two directions. An effort has been made to avoid cutting too much of the smaller young timber; first, because it will make the most profitable growth, and second, because it will furnish, if cut, a larger proportion of small-sized material than the market can absorb. Latitude has been allowed, too, for those in charge of the cutting to use their judgment as to the treatment of stands, after inspection has shown their individual silvicultural condition.

These objects are met by cutting according to two systems: viz., in clear-cut strips, and by selection. Cutting in strips is practised in stands where the trees are even-aged and have small crowns. Where the stand is uniform in character throughout, the strips are laid out in regular order and running up and down the slopes. If there is marked variation in the character of the stand, the strips are located so as to remove the most even-aged or the largest timber, and the cut-over areas become irregular in shape and distribution. Of the stand 25 to 30 per cent is intended to be left uncut, in blocks not less than 150 feet wide, unless in well protected situations. When the timber is removed from strips less than 150 feet wide, the width of the strips left is reduced to that of the cut-over area, but not further.

Selection cutting in pure pine is done in stands where there is a variation of age-classes. This allows the removal of the larger trees while leaving for continued growth the younger thrifty trees. Stands of this character have usually been formed as a result of ground fires which have partially opened up the stand. The trees that have developed in the openings thus formed have deeper and thriftier crowns than the trees grown in the dense even-aged stands, and will therefore make more profitable growth. Reproduction is expected in the small openings made by the logging and this young growth will take the place of the old stand as it is removed in successive cuttings. In marking, an approximate diameter limit of between nine and ten inches is kept in mind, but the main emphasis is laid on leaving a uniform stand, and not

Photo T. W. Dwight

Plate 16 Seed trees Left in Blocks. Note severe windfall in foreground. Deerlodge National Forest, Montana, U.S.A.

Photo T. W. Dwight

Plate 17 Selection Cutting in Lodgepole Pine Stand. Deerlodge National Forest, Montana, U.S.A.

making any openings or too heavily thinned areas that will cause great danger of windfall.

A similar system of cutting is followed in mixed stands of lodgepole pine, spruce, alpine fir ("balsam"), and limber pine, the individuals of which are usually diversified in age as well as species. These stands are mainly on upper slopes, and do not give evidence of as frequent occurrence of fire as the pure pine stands. They resemble more closely than any other type some of the stands in the Rocky Mountains Forest Reserve in Canada. The pure spruce stands have all been of very large tall timber and on a very moist soil, so that the danger of wind-fall was great. On account of the restricted size of the stands, which made it possible to leave belts of seed-trees within reasonable distances of all parts of these areas, they have all been cut clean in doing which the restrictions of the strip system were observed.

Applicability to Stands in Alberta.

In pine stands of the Canadian Rockies, the selection system can be applied to a much smaller extent than in Montana, since the northern stands are more even-aged and uniform, and therefore adapted more to clear-cutting systems. Also the heavier ground-cover usually found in the north makes reproduction of pine on the natural seed-bed more difficult there, and it would not be reasonable to expect young trees to start in the small openings made by a selection cutting. Thus, clear-cutting in strips appears to be the system most applicable.

A different attitude than that assumed in Montana must be taken toward spruce stands, because they are much more extensive in Canada. Their larger area in the north makes it practicable to follow methods of cutting that will protect the trees reserved from being cut, secure reproduction of the spruce and maintain the stands permanently as spruce stands.

BITTERROOT AND KOOTENAI NATIONAL FORESTS.

In western yellow pine and Douglas fir stands which were visited on the Bitterroot and Kootenai National Forests, a system of cutting was followed which is not directly applicable to Alberta stands, but is of indirect interest. This type is made up mainly of yellow pine of large average diameter in stands rather open, compared to spruce and lodgepole pine stands. The underbrush is very light, but grass grows in considerable quantities. To obtain reproduction, a considerable number of trees must be left for seed, and the crown cover should not be entirely destroyed or the grass will get too strong a foothold. The method adopted was to remove approximately two thirds of the timber, taking the larger and defective trees, and leaving thrifty trees distributed as uniformly as possible. About 8,000 feet, board measure, per acre were left on the average. A diameter limit of 18 in., very loosely applied, served as a guide in marking. The amount of timber left was sufficient to make a second cut profitable when young growth had become established, and, in the meantime, profitable growth will be made by the trees. This system would be applicable to Douglas fir stands in which the average size of the individual trees was large. Such stands, however, are in Alberta limited in extent.

BRUSH DISPOSAL AND MARKING.

On all the timber sale areas visited, the brush was disposed of by burning, and, in practically all cases, it was placed in round piles and set on fire after a fresh fall of snow had covered the ground and piles. The piling was done by the fellers and swampers, and the burning by the forest rangers, in some cases with assistance where

Photo T. W. Dwight.

Plate 18 — Clearcut Strips. (Deerlodge National Forest, Montana, U.S.A.)

Photo T. W. Dwight.

Plate 19 — Clearcut Strip (showing logs, cordwood and brush-piles. Deerlodge National Forest, Montana U.S.A.)

required from the employees of the lumber companies. In selection cuttings on the Deerlodge Forest a successful beginning had been made at burning the brush immediately after the felling of the trees.

The marking of timber to be cut was very thoroughly done. When the timber was cut in strips, the boundaries of the areas to be reserved were blazed. In selection cuttings, every tree to be cut was blazed both at breast-height and below stump-height. All blazes were stamped 'U. S.' with a die on the back of the marking axe.

VOLUME, GROWTH AND YIELD TABLES.

Most of the tables are based on measurements taken of trees felled in logging operations on timber limits in the Crowsnest Valley. All the trees on eight plots in different locations, comprising one and a half acres, were measured for diameter and height growth, and also for volume to furnish data for a volume table and to give the volume of the present stand. The yield at different ages was computed from the growth and volume figures. Only trees ten inches and over were measured, as that was the merchantable limit.

The measurements were taken in fully stocked, normal mature stands in order to get growth figures that would be conservative when applied to individual trees or to stands of less density. The measurement of all the trees on the plots was done in order to get a correct average, and to get the proper proportion of large and small trees. It also enabled the computation of yield per acre.

VOLUME.

The diameter inside bark of the top of each log was measured and the volume of the tree computed according to the Scribner log rule.

DIAMETER-GROWTH.

Diameter growth was measured on the stump by decades. The growth figures for each plot were averaged and plotted separately in order that the growth of average trees for each plot might be known and used in computing the yield of each plot at various ages. The plots were classified into two sites and from the curves of the individual plots, the average growth on the two sites was obtained. The average growth of all the trees measured was also computed and plotted.

HEIGHT-GROWTH.

The age of the upper end of each log was counted, and the lengths of logs and top measured. The height figures were averaged similarly to the diameter figures. The time required to grow to stump height was counted in.

SEEDLING HEIGHT-GROWTH.

The table is based on figures obtained in various localities under average conditions.

YIELD.

The volumes of the trees as actually scaled on each plot were added together, and the present stand per acre obtained. The intermediate yields were computed by calculating the dimensions of average trees for the plots. The growth of imaginary trees possessing those dimensions was found from the growth-curves. By consulting the volume table, the volumes of the imaginary trees at various ages were

computed: by multiplication by the number of trees on the plots, the yields of the plots at various ages were determined. The plots were classified according to site and the average yields for each species of tree on each site were determined. An eight-inch merchantable diameter limit was assumed. The factor of decimation was neglected, but as decimation is not rapid after merchantable size is reached, the effect is probably not great, since the yield is figured in board measure. It is also a conservative factor since it tends to make the early yields light. The method would not be entirely applicable to obtaining a table of yield in cubic feet.

As the table is based on such a small area, and on measurements of mature stands only, it can be considered as tentative only. It shows, however, the relation between spruce and pine, and is believed to be near the truth. The plots taken are fully stocked and about 'normal' in the technical sense of that term. Large stands will fall below the table in yield, as most actual stands are below normality. Normal stands, however, give the truest data of the growth of a species. Studies of average stands can in the future be made more rapidly and on a larger scale, but these tables will obviate the necessity of gathering many of the classes of data which have been used in their preparation.

TABLE 12.

VOLUME TABLE FOR ENGELMANN SPRUCE.

(190 trees; top diameter, 5 inches; height of stump, 2-3 feet; Scribner log rule.)

Diameter at Breast-height.	Height of Tree (Feet)						
	50	60	70	80	90	100	110
	Volume (Feet, Board Measure).						
Inches.							
8	15	20	30				
9	25	35	45				
10	40	50	60	80			
11	50	65	80	100			
12	60	80	100	120	150	180	
13	70	95	120	140	170	200	
14	85	110	140	160	200	230	
15			160	190	230	260	
16			170	210	260	300	350
17				240	290	340	390
18				270	320	370	430
19				300	350	410	470
20				330	380	450	510
21					420	490	560
22					460	530	610
23					500	570	660
24					550	620	710

TABLE 13.

VOLUME TABLE FOR LODGEPOLE PINE.

(73 trees; top diameter, 5 inches; height of stump, 2·0 feet; Scribner log rule.)

Diameter at Breast-height	Height of Tree (Feet).					
	50	60	70	80	90	100
	Volume (Feet, Board Measure).					
Inches.						
8	25	40	50			
9	40	50	70	80		
10	50	65	80	90	100	
11	65	80	90	100	120	
12	80	100	110	120	140	
13	90	120	130	140	160	
14		130	150	160	180	250
15		150	170	190	230	280
16				220	260	330
17				250	300	380
18				280	340	420
19					380	480
20					420	530

TABLE 14.

DIAMETER-GROWTH OF ENGELMANN SPRUCE, LODGEPOLE PINE AND DOUGLAS FIR.

Age.	Engelmann Spruce.			Lodgepole Pine.			Douglas Fir.
	215 trees measured.			73 trees measured.			4 trees measured.
	Aver.	Site I.	Site II.	Aver.	Site I.	Site II.	Average.
	Diameter at breast height inches.						
Years.							
10.	1·1	1·2	1·0	2·2	2·4	2·0	1·4
20.	2·2	2·5	2·1	3·9	4·4	3·5	3·0
30.	3·2	3·8	2·9	5·4	5·9	4·9	4·5
40.	4·3	5·1	3·7	6·7	7·2	6·2	6·0
50.	5·3	6·4	4·7	7·8	8·3	7·4	7·4
60.	6·3	7·7	5·6	8·8	9·3	8·3	8·6
70.	7·3	8·8	6·3	9·6	10·1	9·2	9·6
80.	8·2	9·8	7·0	10·3	10·7	9·9	10·5
90.	9·0	10·9	7·9	10·7	11·1	10·3	11·2
100.	9·7	11·9	8·6	11·0	11·4	10·7	11·8
110.	10·4	12·7	9·2	11·3	11·7	11·0	12·5
120.	11·1	13·5	9·9	11·6	12·0	11·3	13·1
130.	11·7	14·2	10·5	11·9	12·3	11·5	13·6
140.	12·3	14·8	11·1	12·1	12·6	11·7	14·2
150.	12·9	15·4	11·7	12·3	12·8	11·9	14·8
160.	13·5	16·0	12·2	12·5	13·1	12·1	15·4
170.	14·0	16·6	12·8	12·7	13·3	12·2	16·0
180.	14·6	17·2	13·2	12·9	13·6	12·4	16·6
190.	15·1	17·7	13·8	13·1	13·8	12·6	17·1
200.			14·2	13·3	14·0	12·8	17·6

TABLE 15.

HEIGHT-GROWTH OF ENGELMANN SPRUCE, LODGEPOLE PINE AND DOUGLAS FIR.

Age	Engelmann Spruce.			Lodgepole Pine.			Douglas Fir
	215 trees measured.			73 trees measured.			26 trees measured.
	Aver.	Site I.	Site II.	Aver.	Site I.	Site II.	Average.
	Height (feet).						
Years.							
10				7	7	7	2
20	3	4	3	14	15	14	4
30	7	8	6	26	27	25	8
40	12	15	10	36	38	35	15
50	19	24	16	45	47	44	24
60	27	33	23	54	56	52	32
70	35	43	31	61	64	58	40
80	43	51	39	65	69	62	48
90	51	58	46	69	73	66	54
100	58	65	53	72	77	69	59
110	63	70	58	74	79	71	64
120	67	75	62	76	80	73	68
130	71	79	65	78	82	75	72
140	74	83	68	78	83	76	76
150	77	86	71	79	84	76	79
160	79	88	74	79	84	76	81
170	81	90	76	80	84	77	84
180	83	91	78	80	84	77	86
190	84	92	80	81	85	77	88
200	85	93	81	81	85	78	90

TABLE 16

[illegible]

H	Engelmann Spruce	Lodgepole Pine	H	Engelmann Spruce	Lodgepole Pine
	Age	Age		Age	Age
Feet	Years	Years	Feet	Years	Years
0 1	1	1	1 1	16	
0 2	2	1	1 2	17	
0 3	4		1 3	17	
0 4			1 4	17	
0 5	6		1 5	18	
0 6	7		1 6	18	
0 7	8		1 7	19	
0 8	9		1 8	19	
0 9	10		1 9	20	
0 10		10	1 10	20	10
0 11	11		1 11	20	10
1 1	11		2 1	21	10
1 2	12		2 2	21	10
1 3	13		2 3	21	11
1 4	13		2 4	21	11
1 5	14		2 5	22	
1 6	14		2 6	22	11
1 7	15		2 7	23	11
1 8	15		2 8	23	12
1 9	16		2 9	24	
		Forest Height.	4 5	26	13

TABLE 17.

NORMAL YIELD-TABLE FOR ENGELMANN SPRUCE AND LODGEPOLE PINE.

Age.	Engelmann Spruce.		Lodgepole Pine.		
	Site I.	Site II.	Site I.	Site II.	Site III.
	Yield per acre.				
Years.	Ft. B.M.	Ft. B.M.	Ft. B.M.	Ft. B.M.	Ft. B.M.
40	.....	.....	2,500	2,000	1,000
50	.....	.....	5,500	4,000	2,000
60	1,000	.....	11,000	6,500	3,500
70	2,500	1,000	16,500	9,500	4,500
80	4,500	1,500	21,000	13,000	6,000
90	7,000	2,500	25,000	16,000	8,000
100	12,000	4,000	28,000	18,500	9,000
110	16,000	6,000	31,500	21,000	10,000
120	22,000	8,000	34,000	22,000	11,000
130	27,000	10,000	36,000	24,000	12,000
140	32,000	13,000	38,000	26,000	12,500
150	36,000	16,000	40,000	27,000	13,000
160	40,000	19,000	42,000	28,500	13,500
170	43,000	22,000	43,000	29,500	14,000?
180	47,000	25,000	45,000	30,000	14,000
190	50,000	29,000	46,000	.....	.....
200	53,000	32,000	46,500	.....	.....

DENSITY AND AVERAGE SIZE AT MATURITY.

Species.	Site.	Age.	Trees per acre.	Aver. diam. breast high.	Average height.	Average volume.
		Years.	Number.	Inches.	Feet.	Ft. B.M.
Spruce	I	200	182	16·5	92	281
	II	200	216	14·1	78	148
Pine	I	200	204	15·1	87	237
	II	180	238	13·4	76	146
	III	180	292	9·3	55	48

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" *25. Forest Products of Canada, 1910: Lumber, Square Timber, Lath and Shingles.

" *26. Forest Products of Canada, 1910: Pulpwood.

" 27. Forest Products of Canada, 1910: Cooperage.

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" 32. The Turtle Mountain Forest Reserve.

" 33. Forest Conditions in the Rocky Mountains Forest Reserve.

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